Spaceflight Seminar

Have you ever wondered why we have launch windows? Or why the attitude of the Space Station changes? Come find out at the **Spaceflight Refresher and ISS Operations Overview** presented by Dr. Jack Bacon from NASA's VIPER team. This half-day seminar will answer some of the many questions about why and how we fly in space.

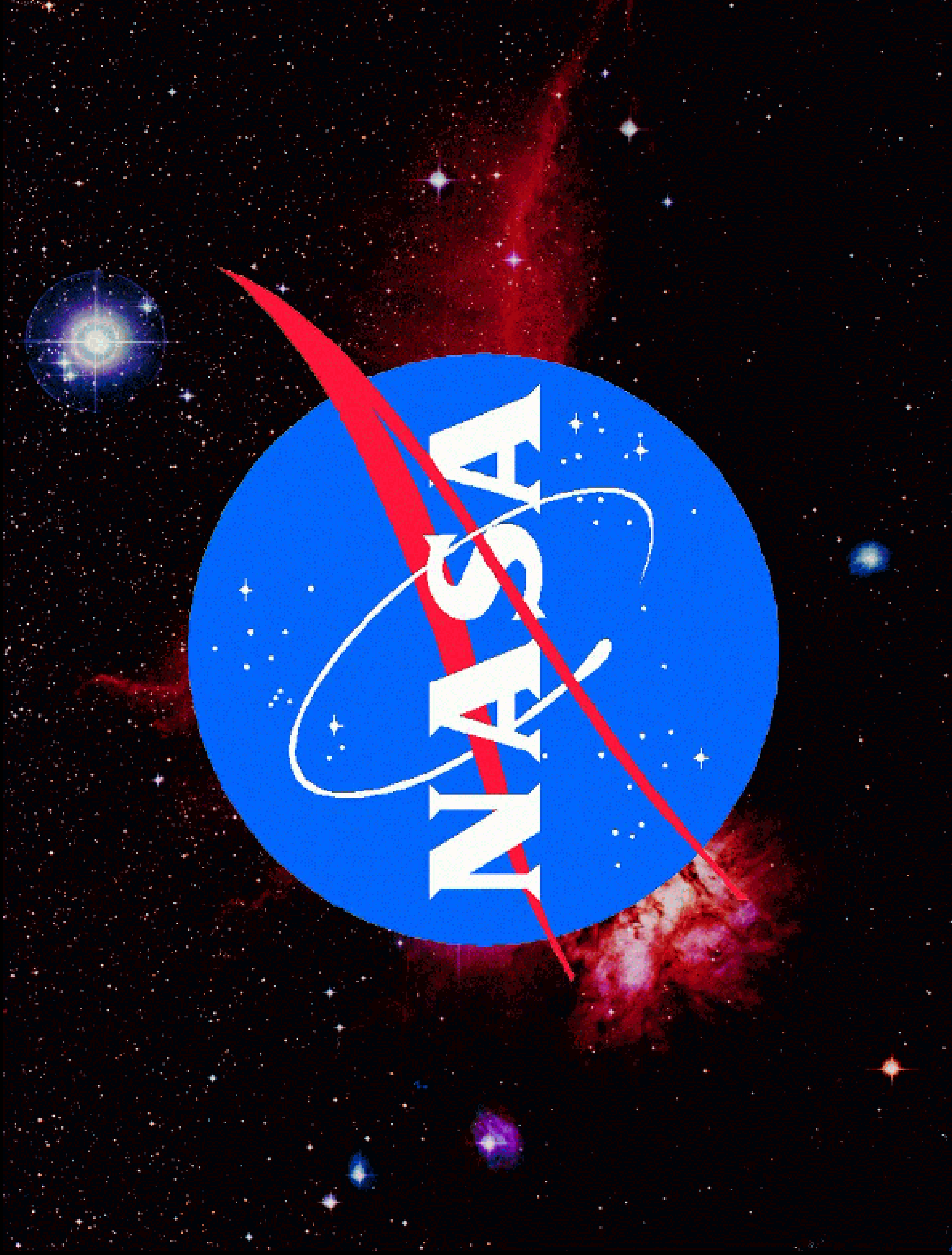
Date: Friday, September 29, 2006
Time: 9:00am to 12:00pm
Location: Conference Center

OE-CSSP and CAO: Register **by September 13** to ensure your spot. After this date, registration will be opened to all CSA employees.
Please register on the intranet at: .

Topics to be covered:
What's so valuable about micro gravity?
How do we get to micro G so close to a huge gravity well like the Earth?
How come such a big rocket gets so little payload to space?
Why do we have daily launch windows, and why are they so short?
What's the beta angle, why does it change so strangely, and why do we care so much about it?
Why do we have launch seasons for the Shuttle? Why can't we just launch any old day?
Why do we see the station some days, not on others, and at different times and directions?
Why do we keep changing the attitude of the Space Station?
What are the certified attitudes of the station, and why did we pick these few?
Why do we keep changing the altitude of the Space Station among these three?
What's the difference between Power Balance, Energy Balance, and Depth-of-Discharge?
Where does all the uncertainty come from in our orbit predictions for phasing, collisions, communications coverage, etc?

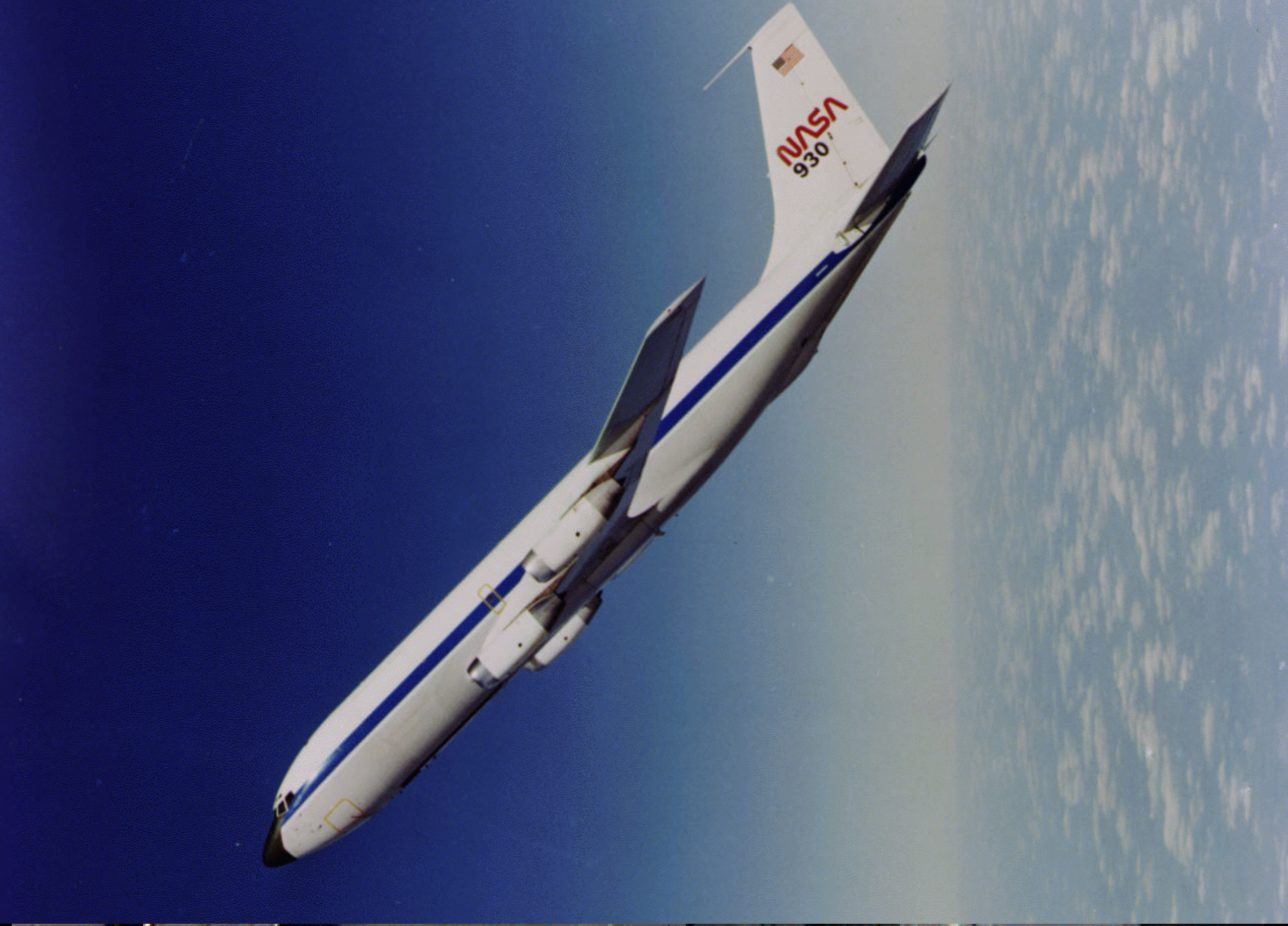
Why do we usually reboost only on days that we do attitude changes?
What's F(10.7), what does it do, why do we care, and why does it vary so much?
Why do we care about orbital phasing of the ISS? Can't we just do phasing with the arriving vehicles?
Why is the Space Station built the way it is?
What's Sun Slicer? (or Night Glider, or Dual Angle, or (coming soon!) Mixmaster, or Outrigger, or...)
What's a BGA, and what is BGA conditioning all about?
What's a Control Moment Gyroscope, and what does it do?
What's a desat? Why is it more trouble now than it used to be?
How much orbital debris is there, and how dangerous is it?
Why aren't we more worried about meteor storms?
What is atomic Oxygen? Where does it come from, and why is it a nuisance?
What's a gravity gradient attitude, and why don't we use it?
How come we see things like phantom torques and phantom spikes and other things that Shuttles and stations and capsules have never seen?

How are all these topics affecting our assembly plans for this year and through the life of station?


NASA

GRAVITY:

It’s not just a good idea…
it’s the <u>LAW</u>.


NASA
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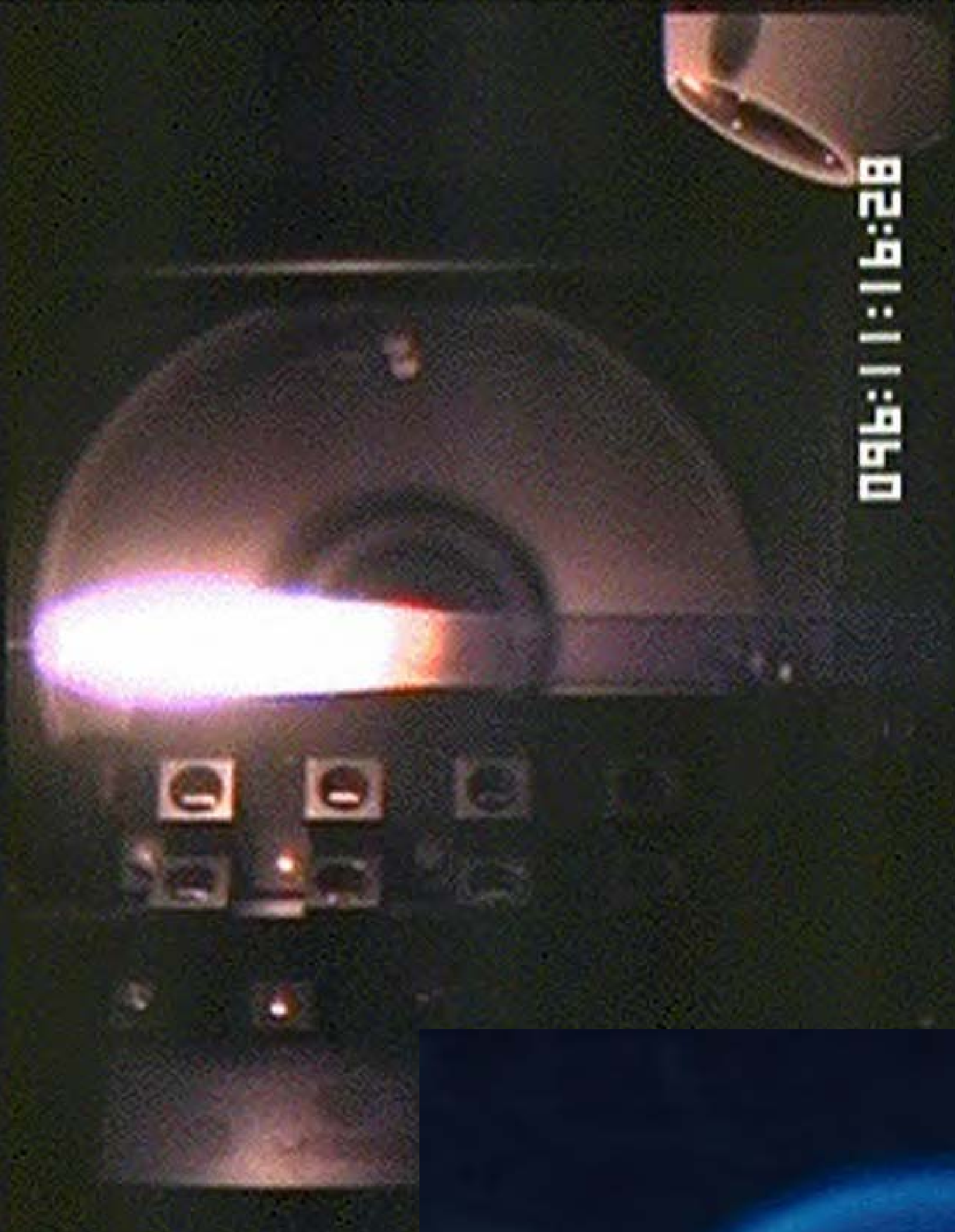
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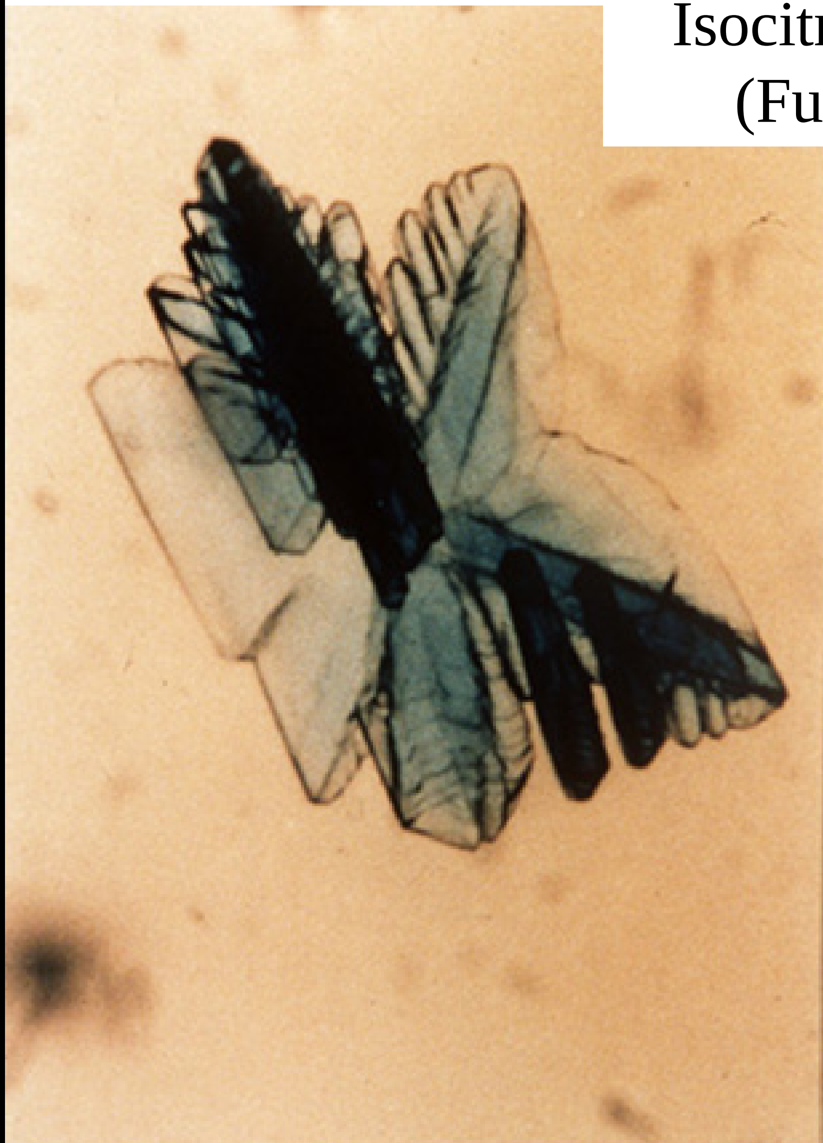
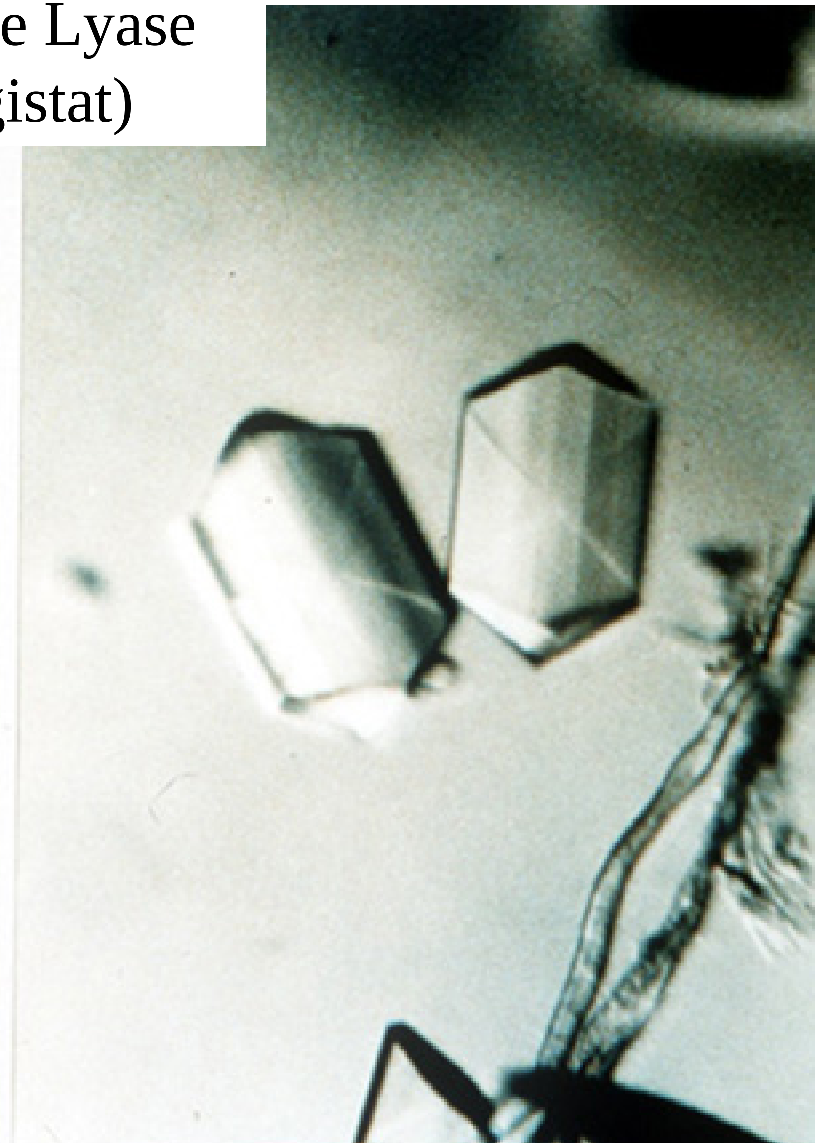
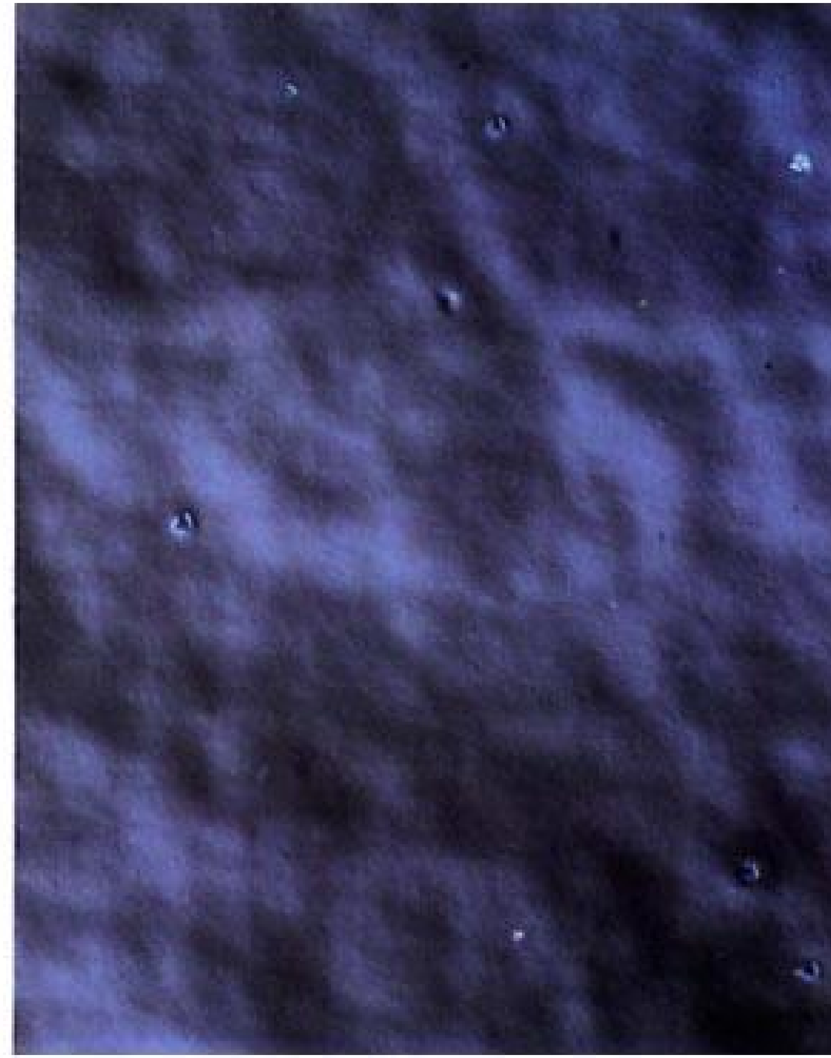
Isocitrate Lyase (Fungistat)



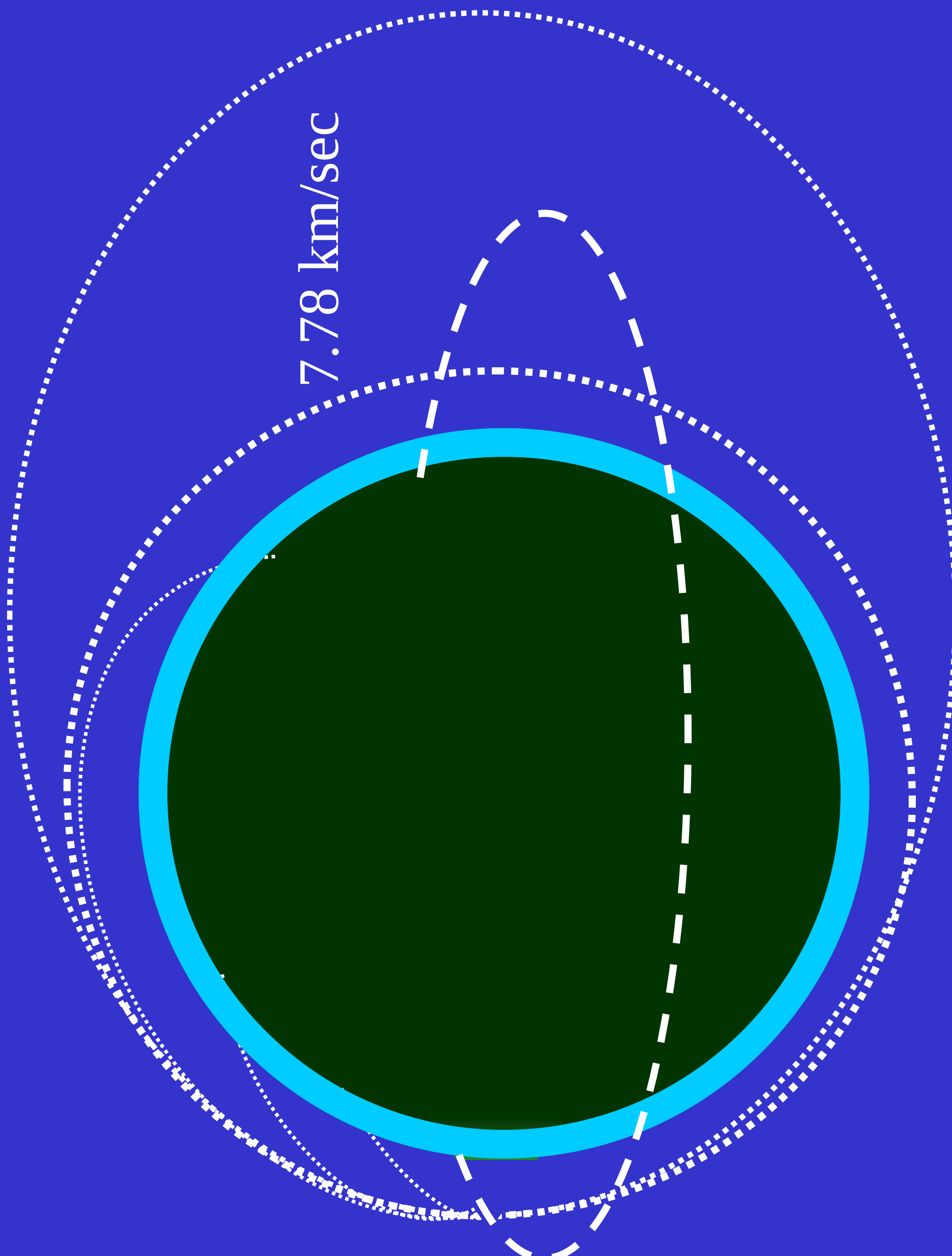


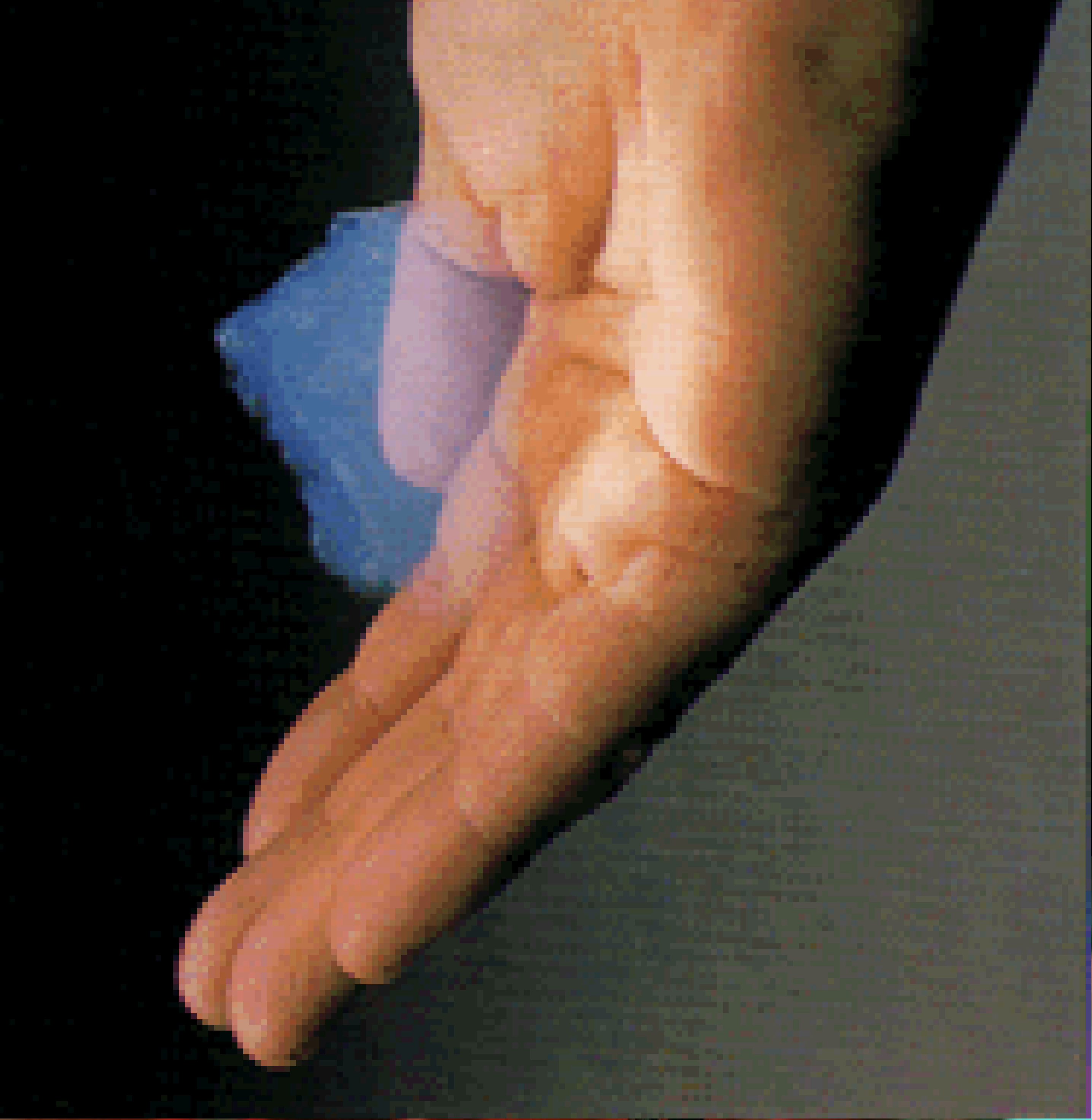
ZnCdHg

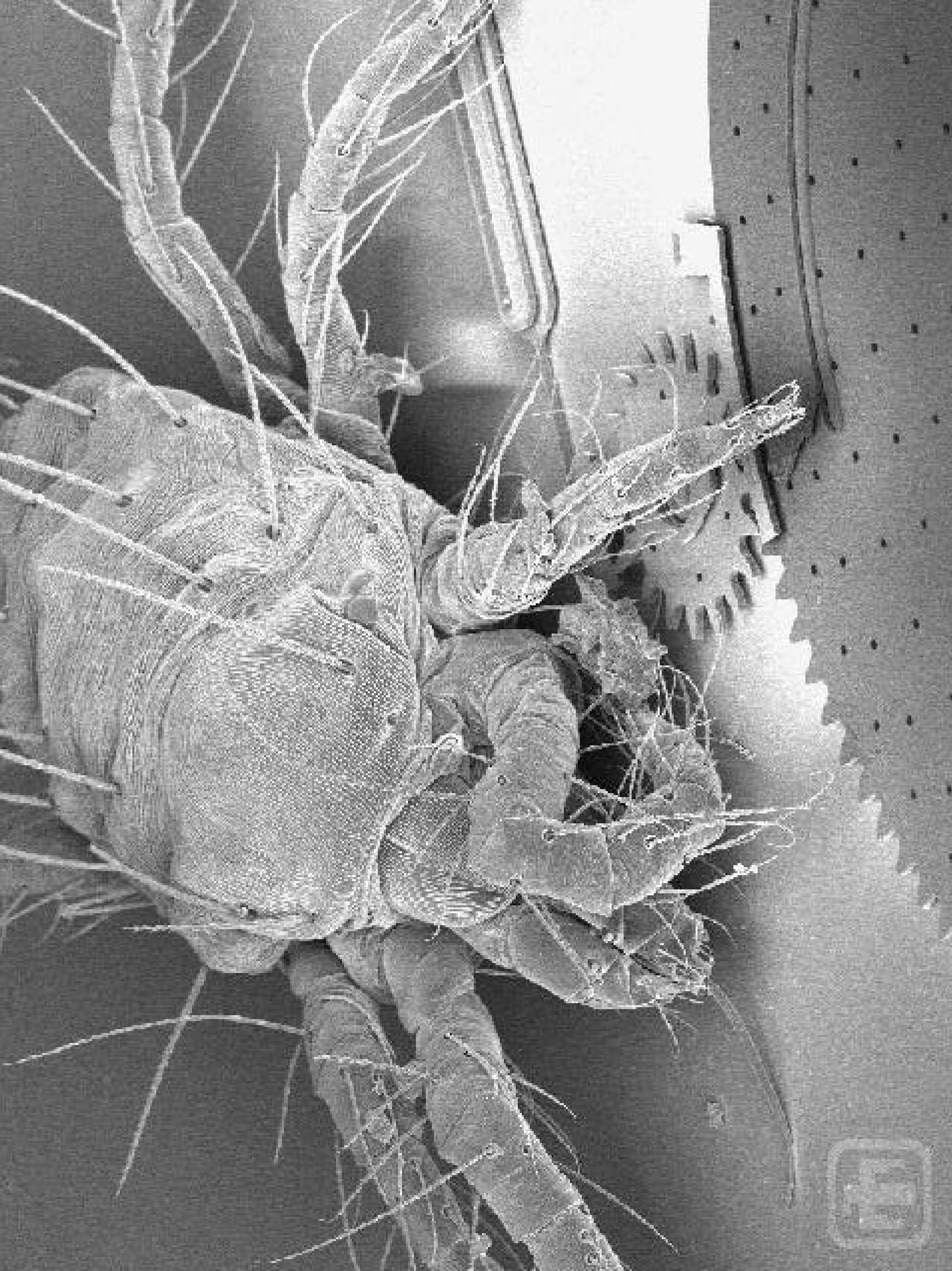


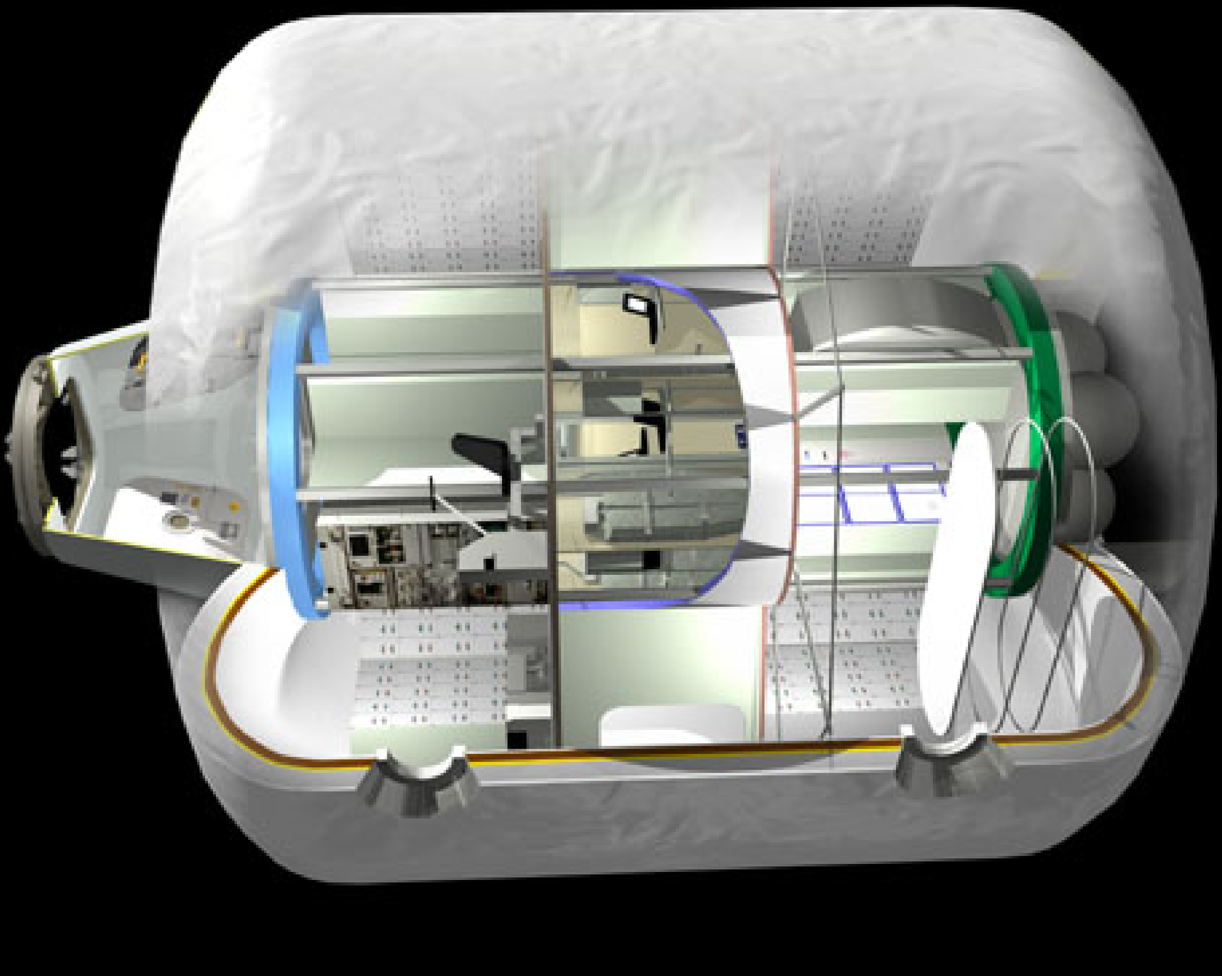
Getting There:

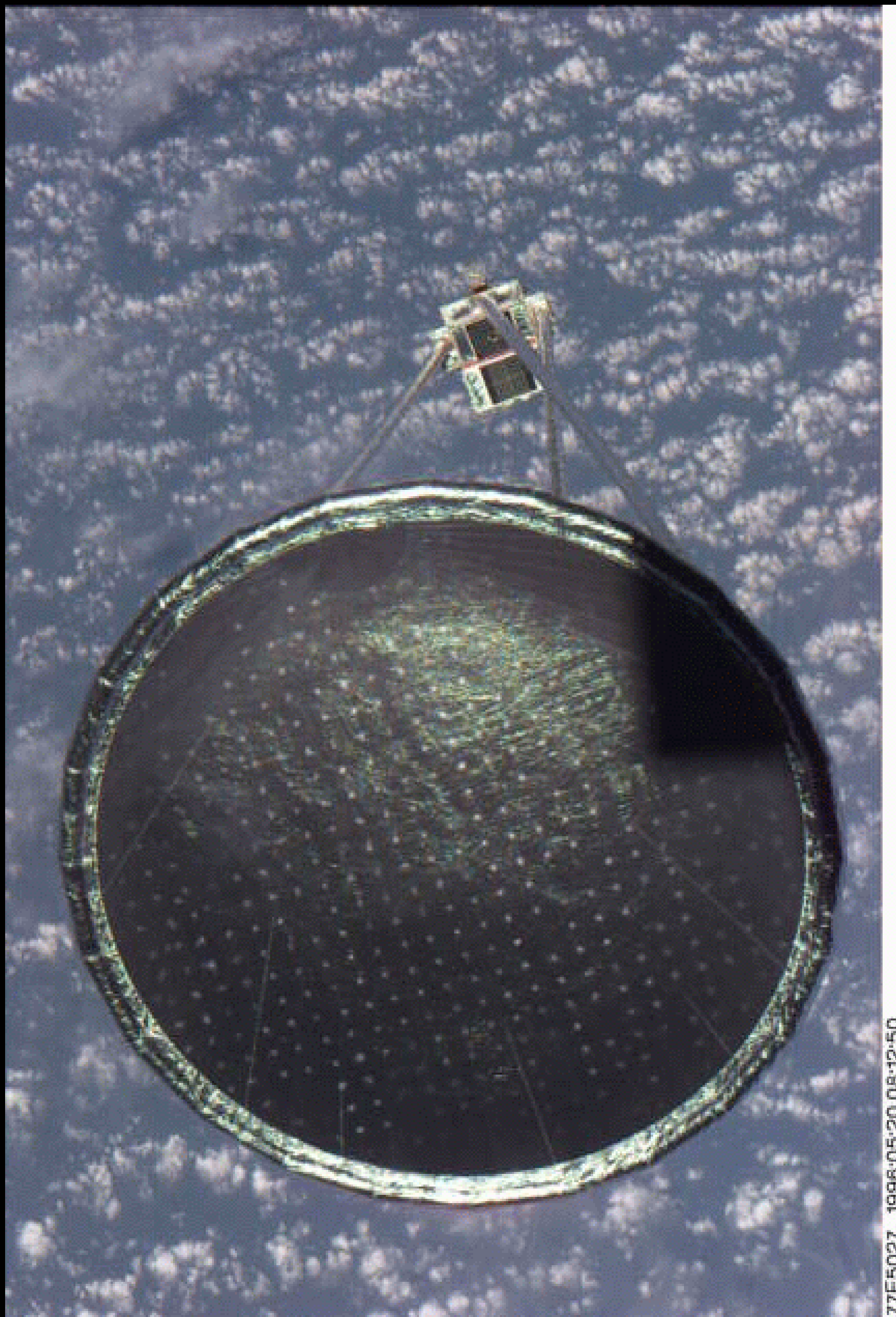
(That first step is a doozie!)


7.78 km/sec



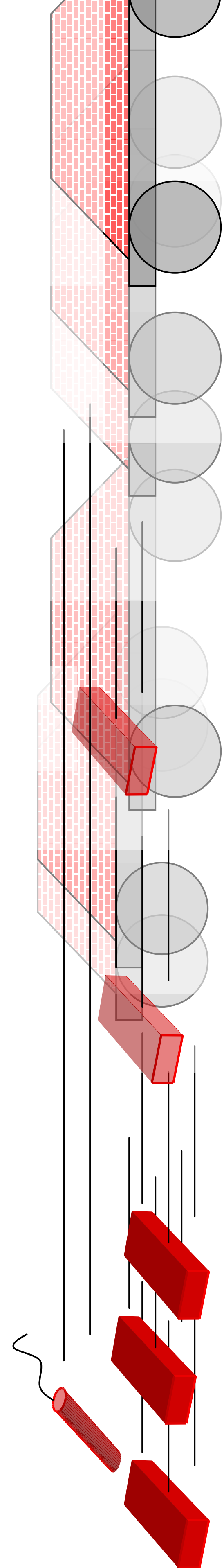


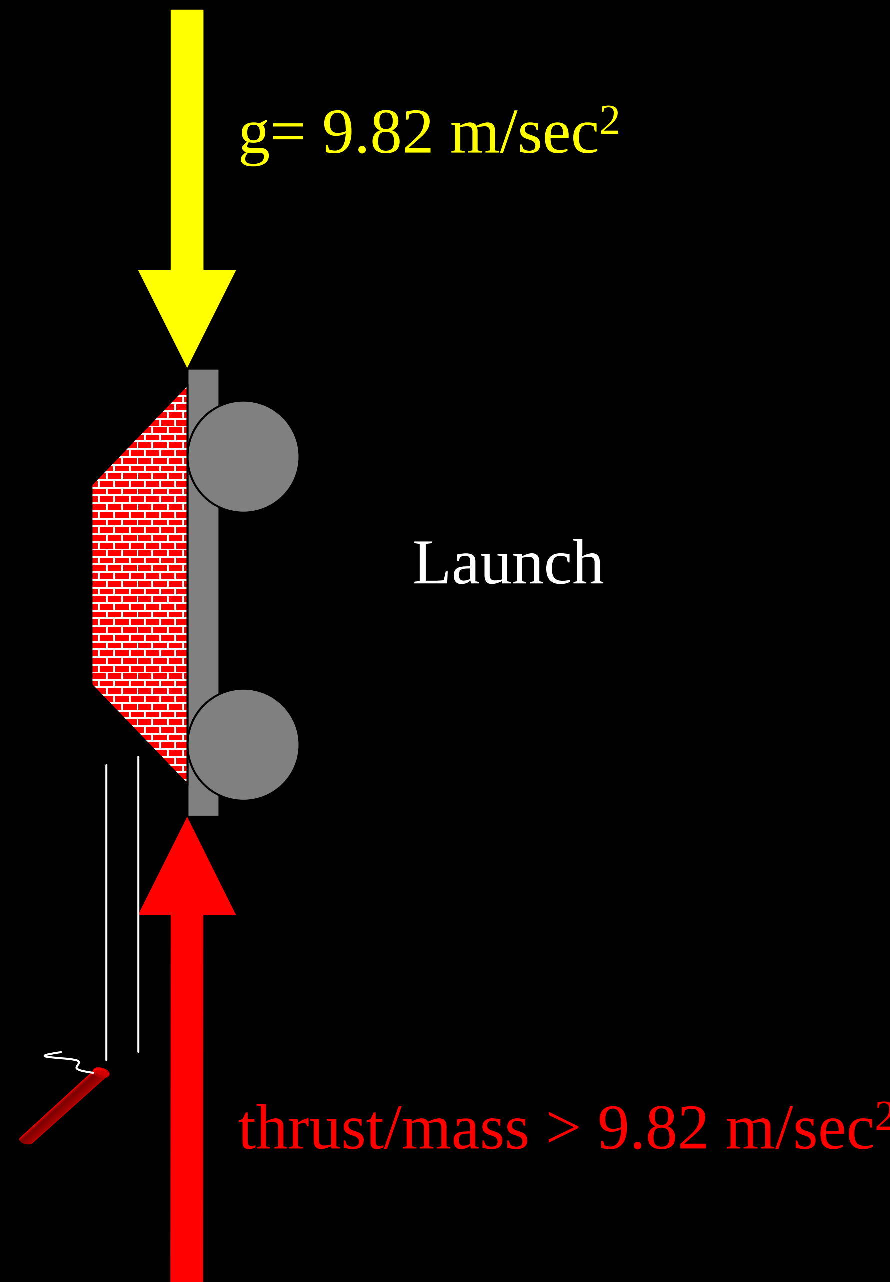



S77E5027 1998:05:20 08:12:50

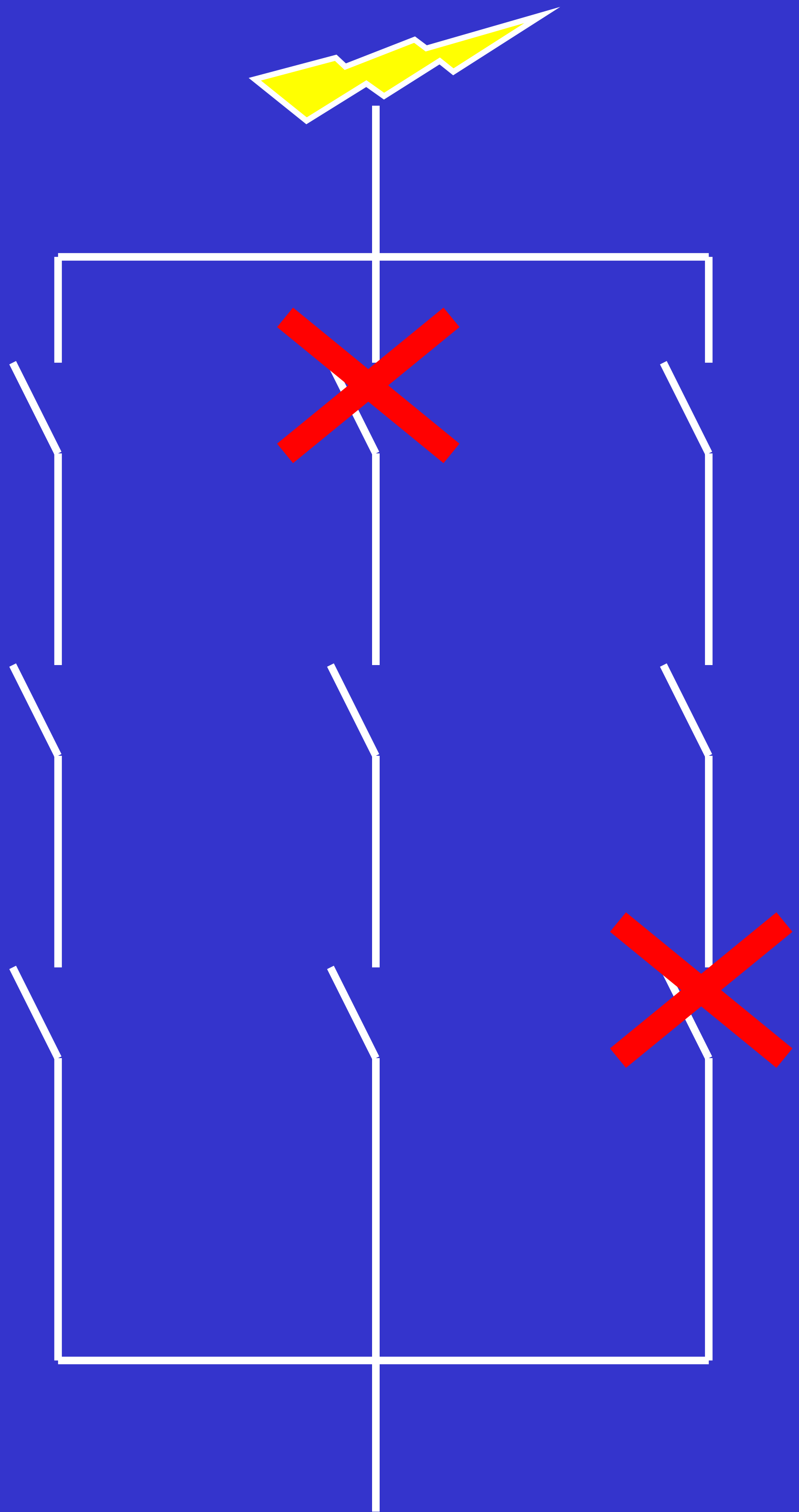
Climbing There:

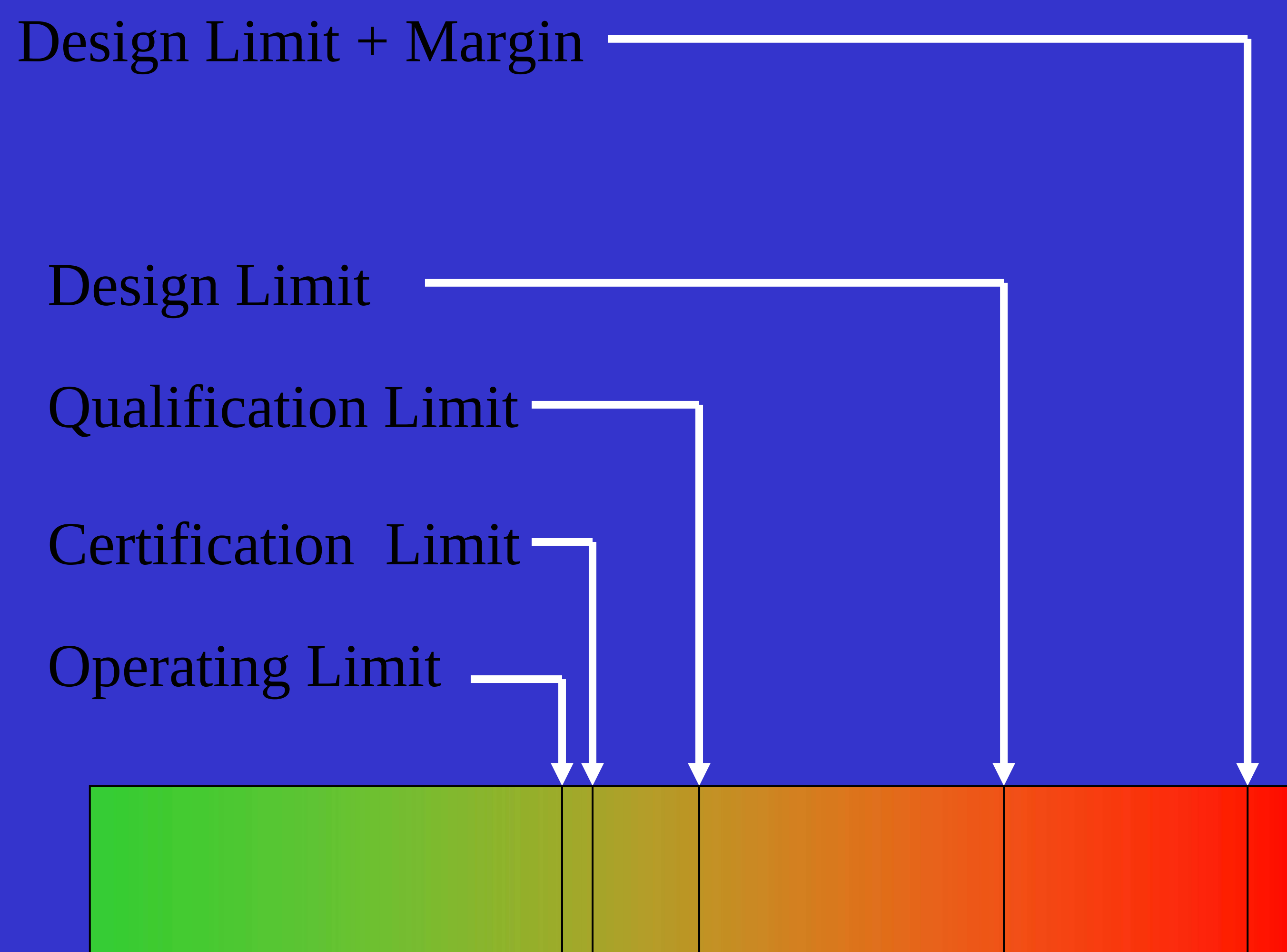
(Getting the lead out…)



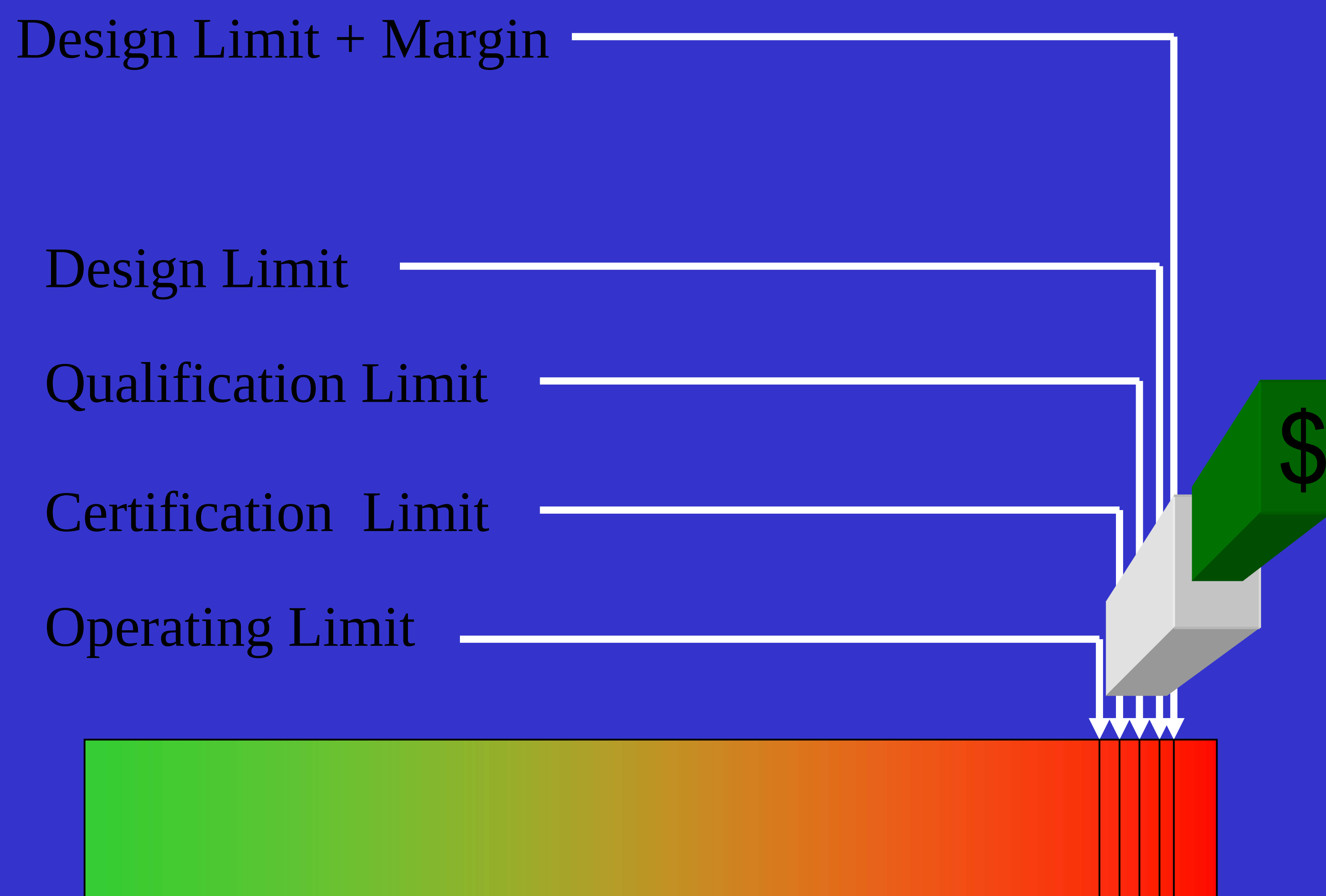


g= 9.82 m/sec2
Launch
thrust/mass > 9.82 m/sec2





Design Limit + Margin
Design Limit
Qualification Limit
Certification Limit
Operating Limit


Design Limit + Margin
Design Limit
Qualification Limit
Certification Limit
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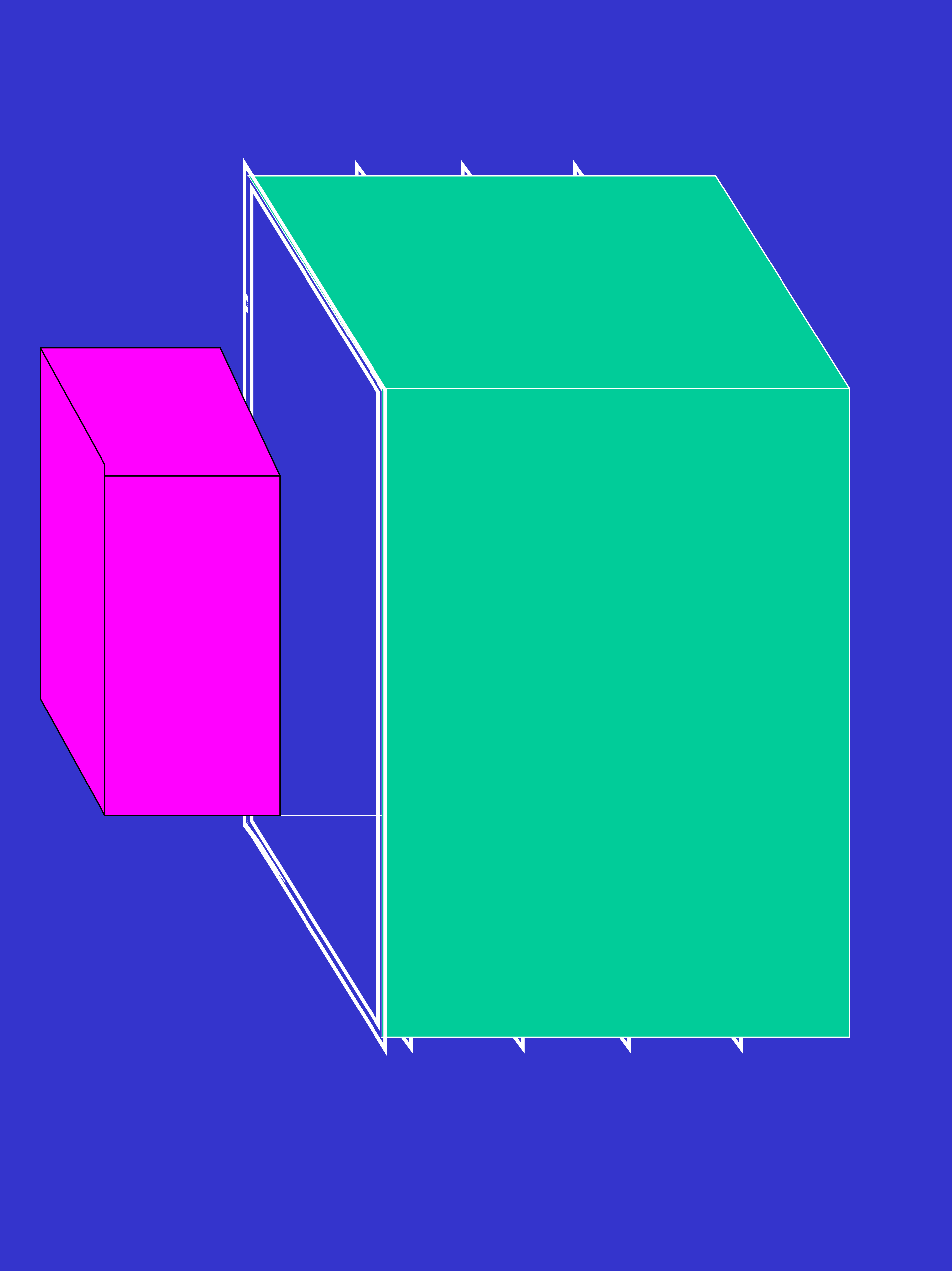
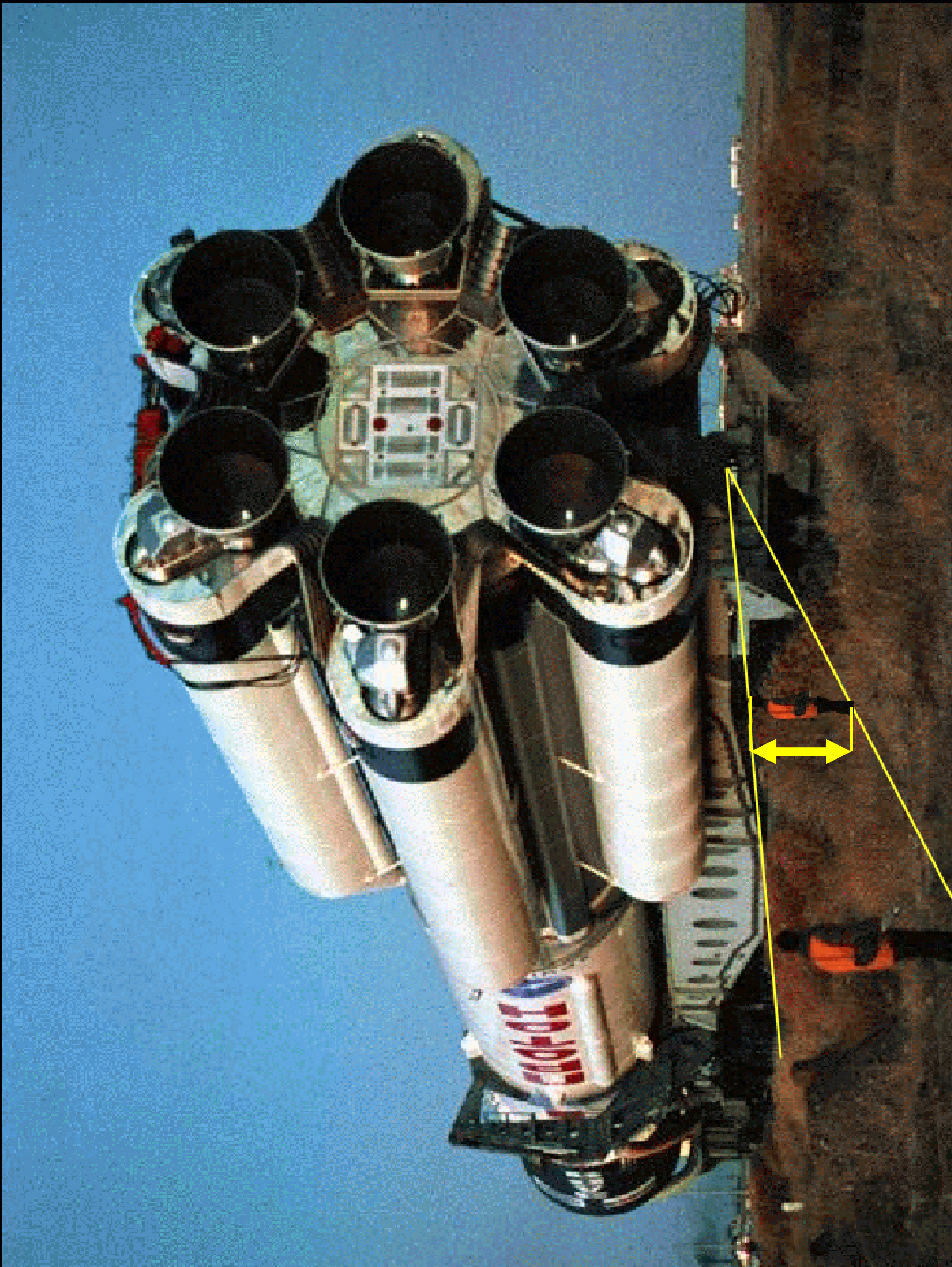
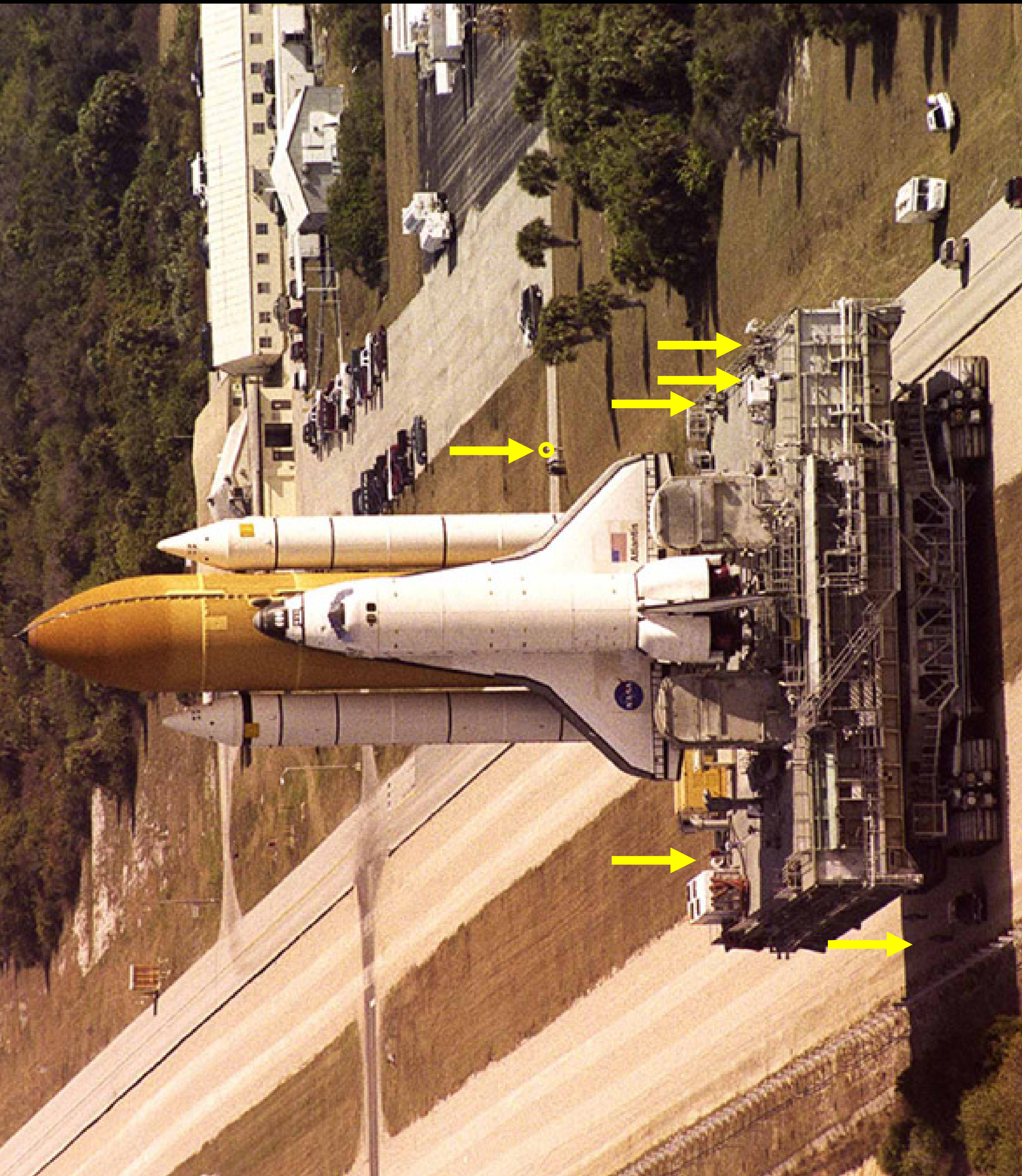
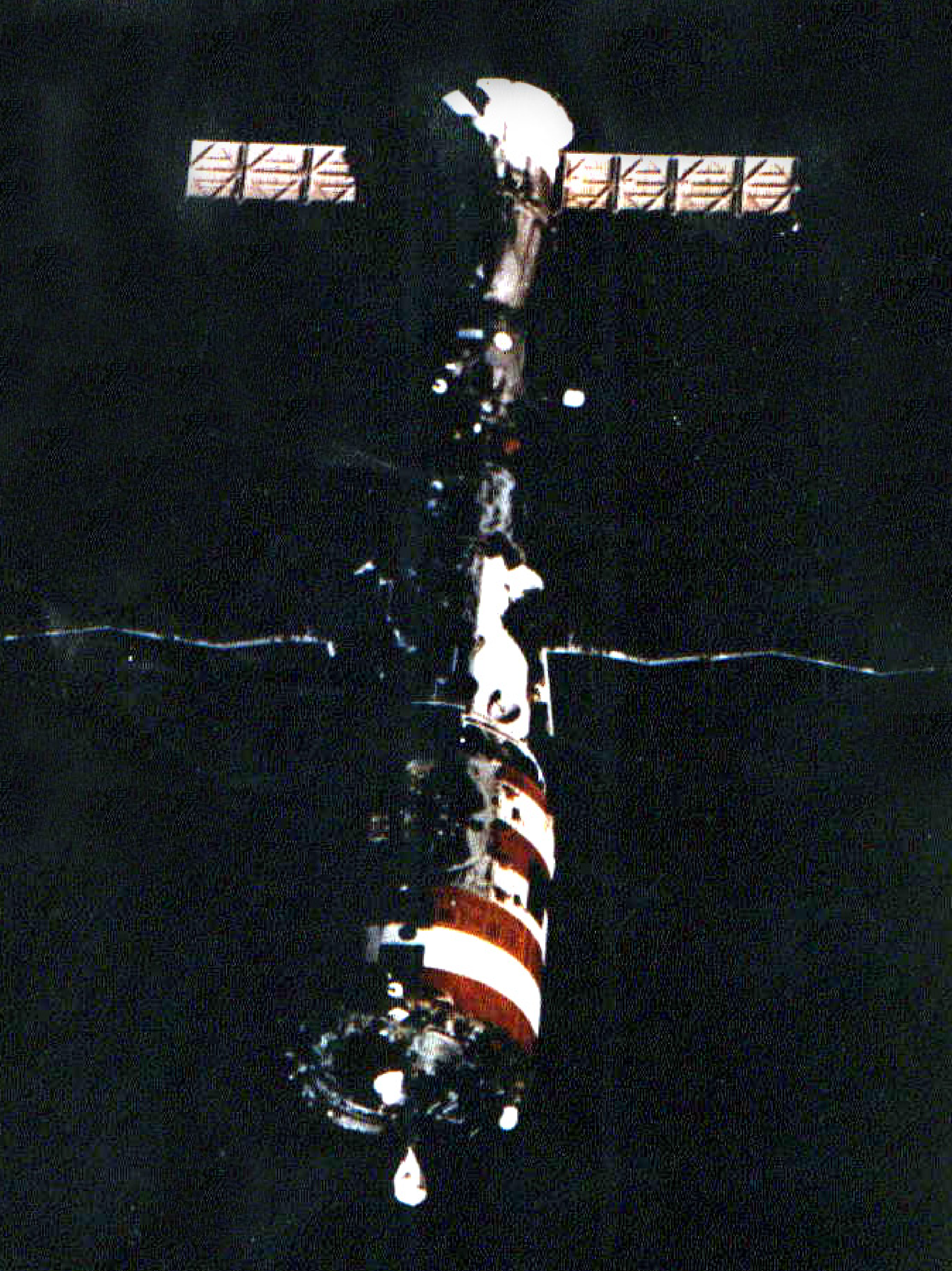
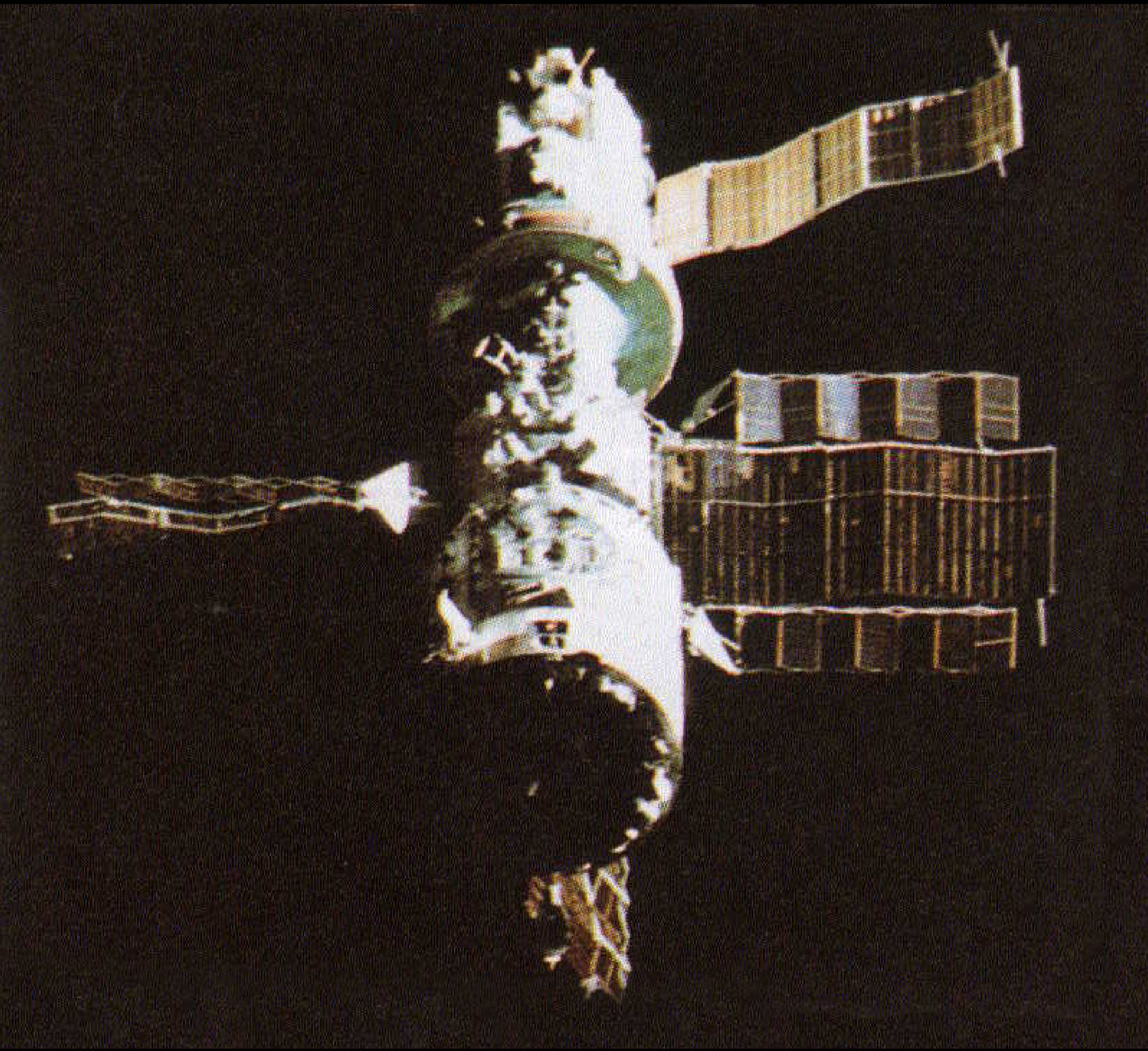
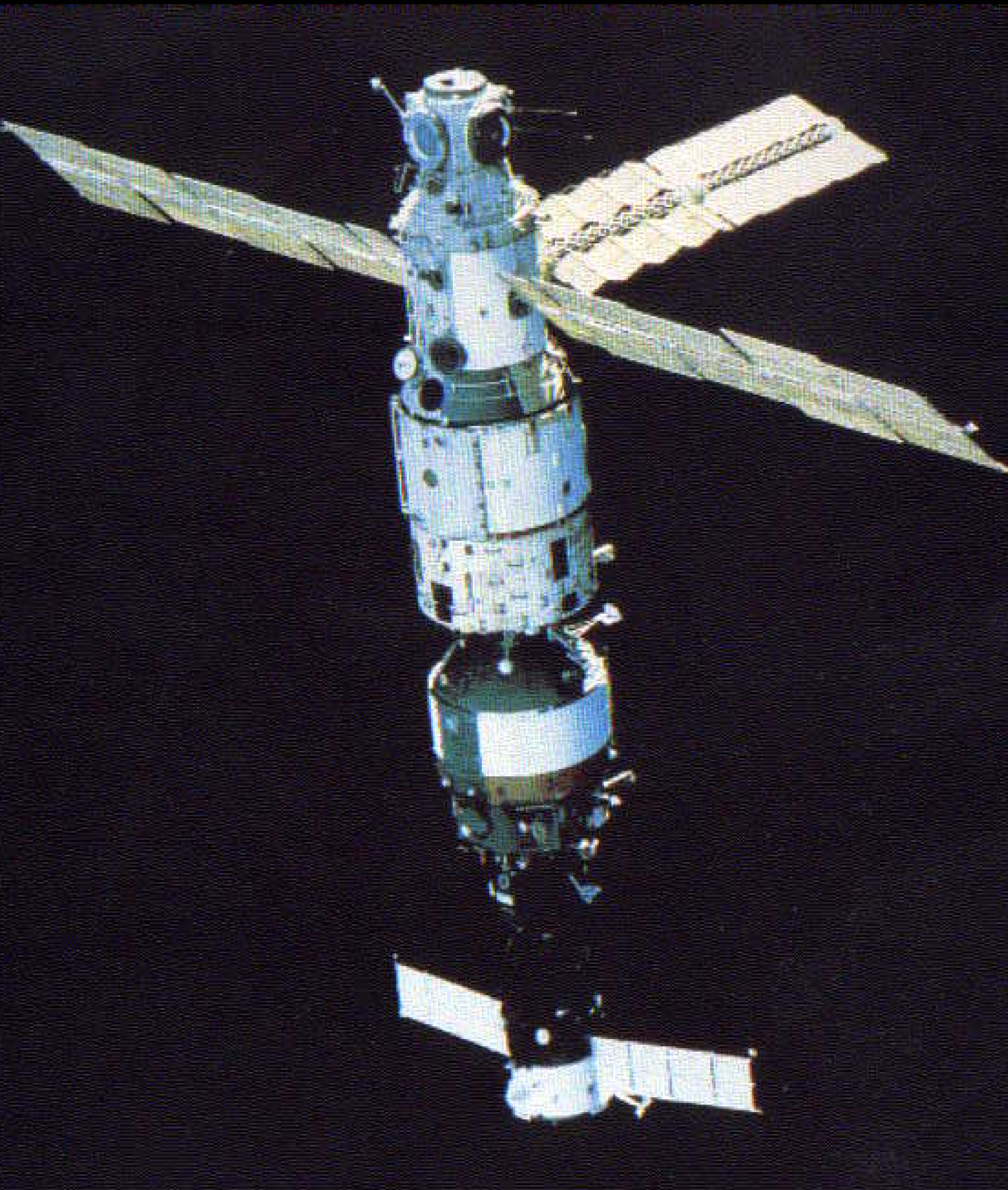


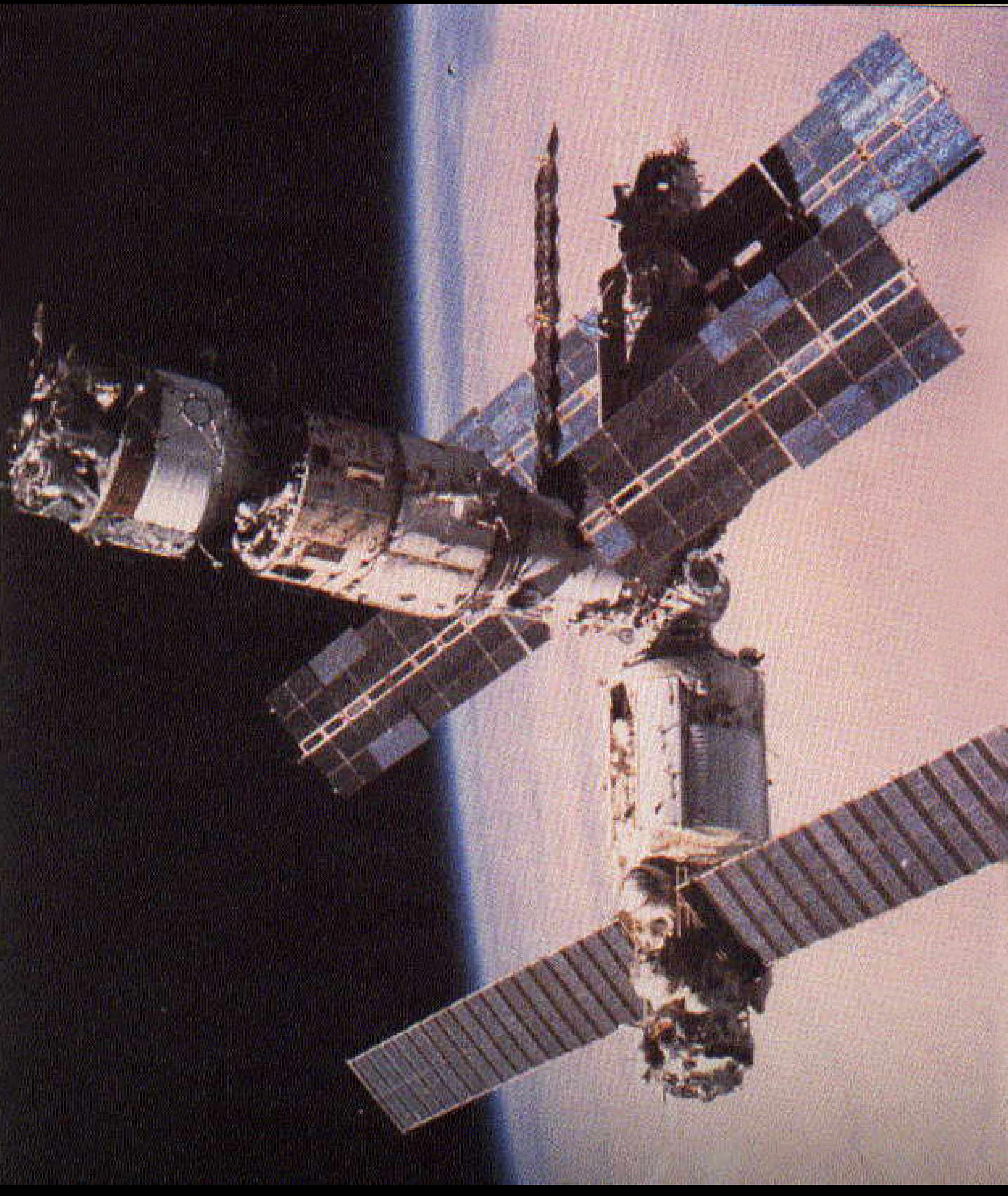


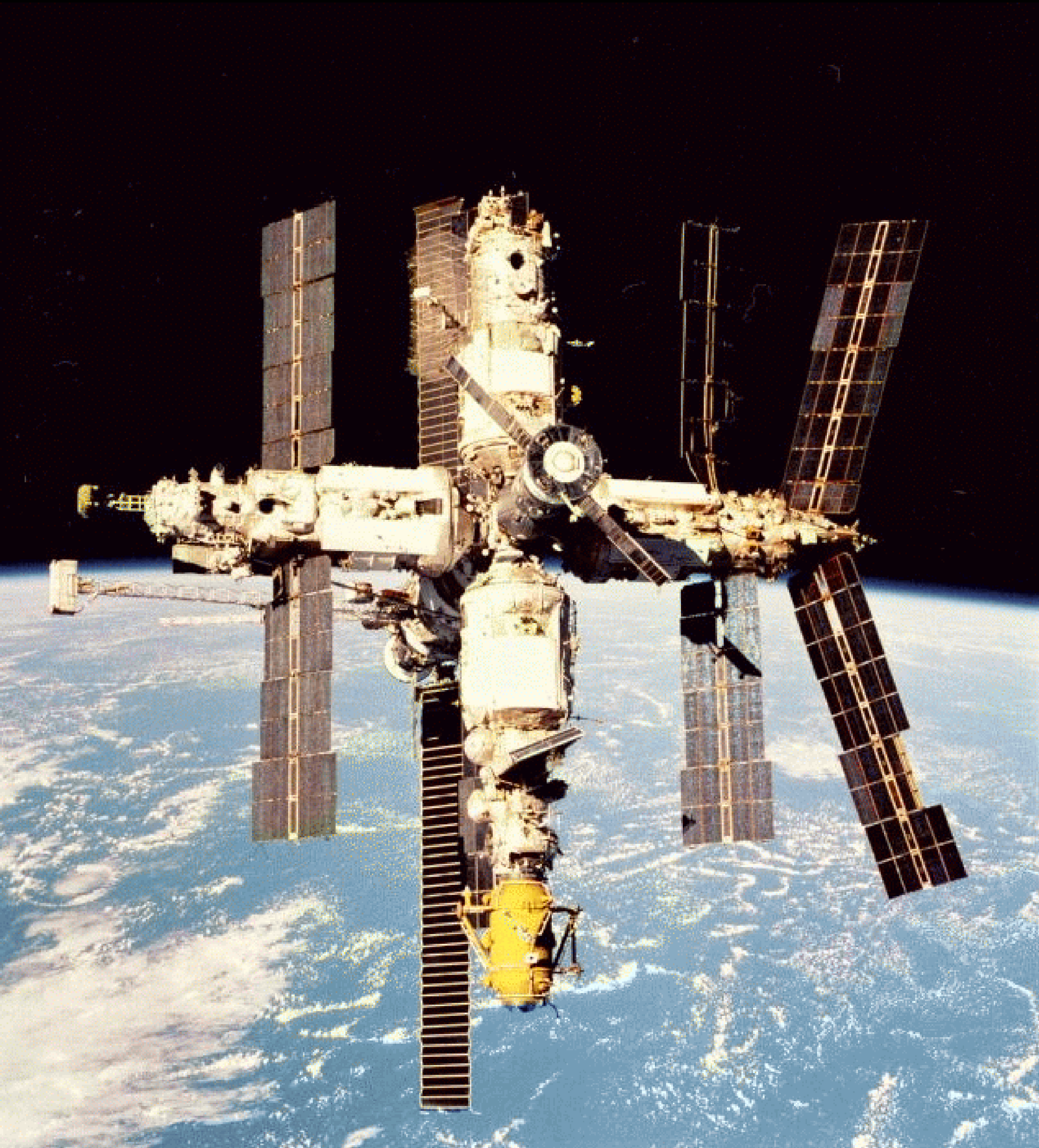




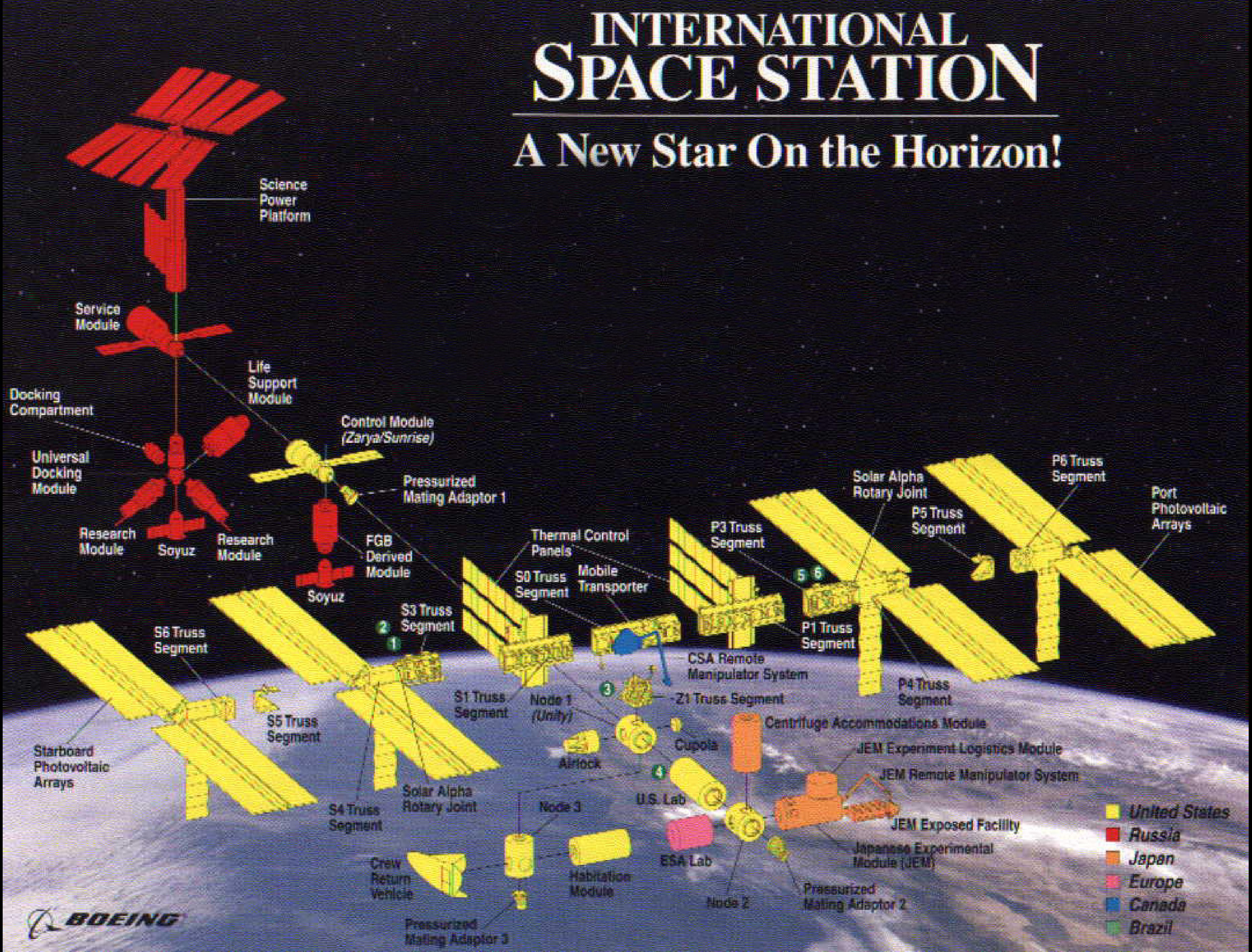




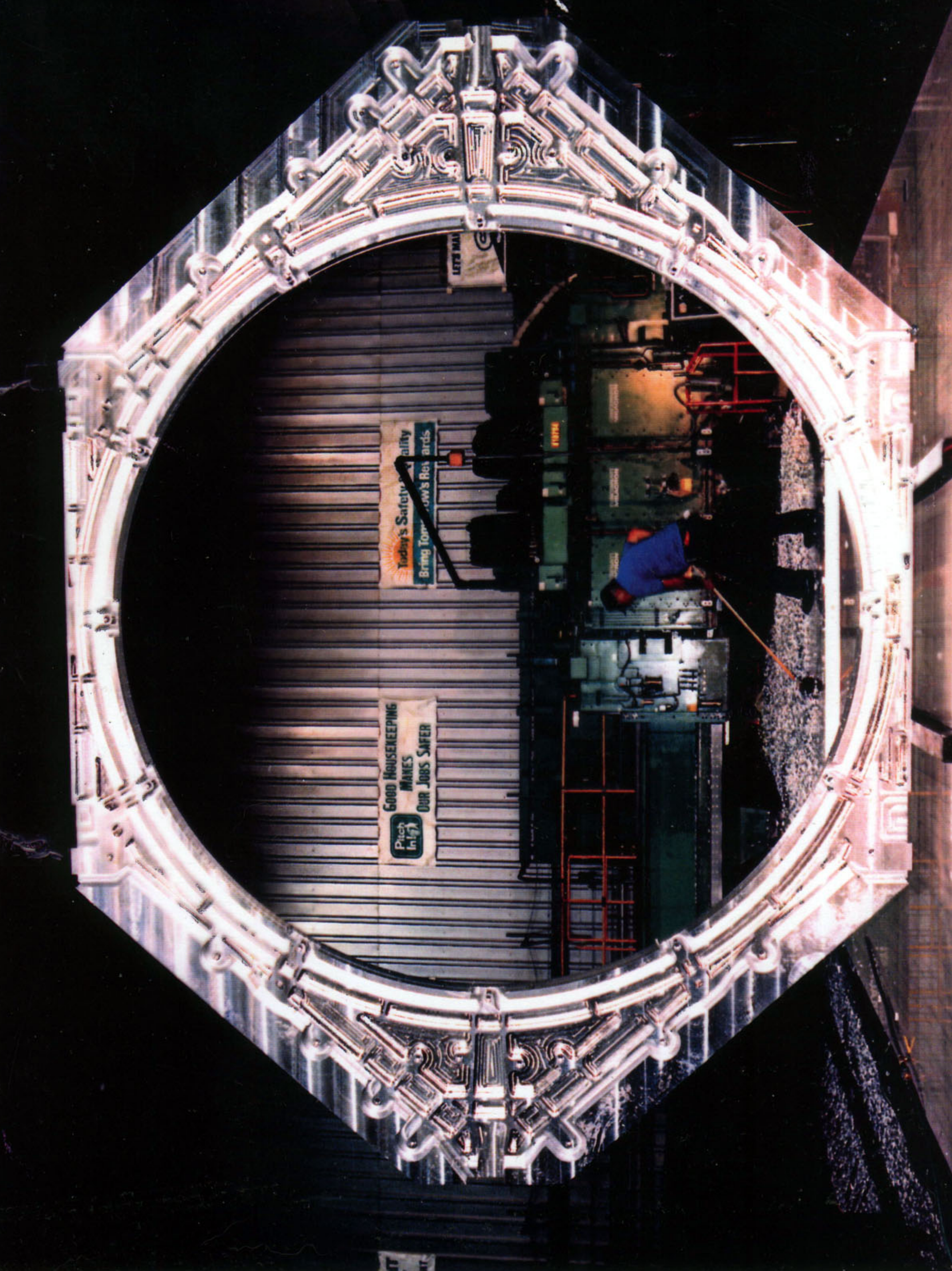


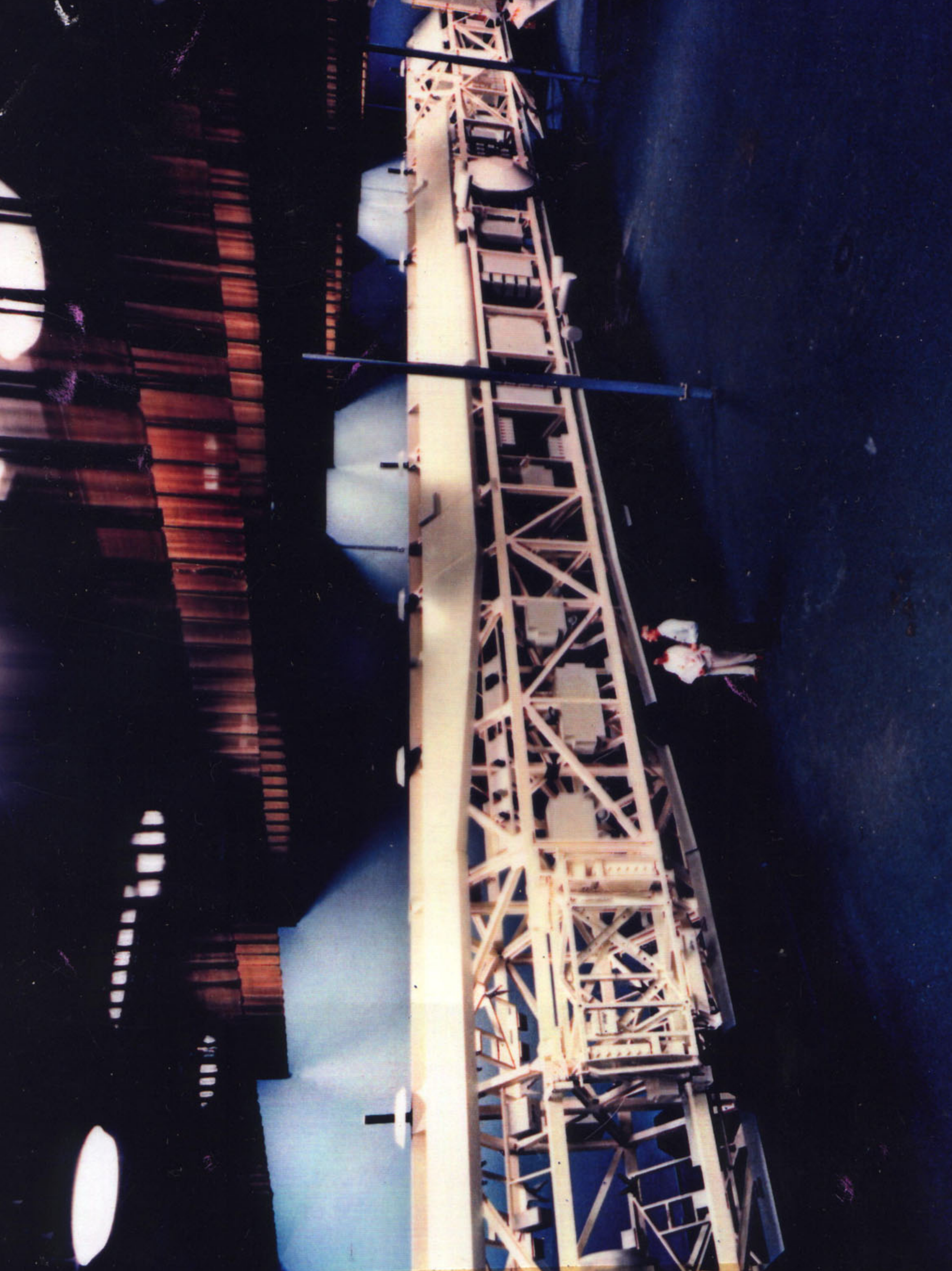


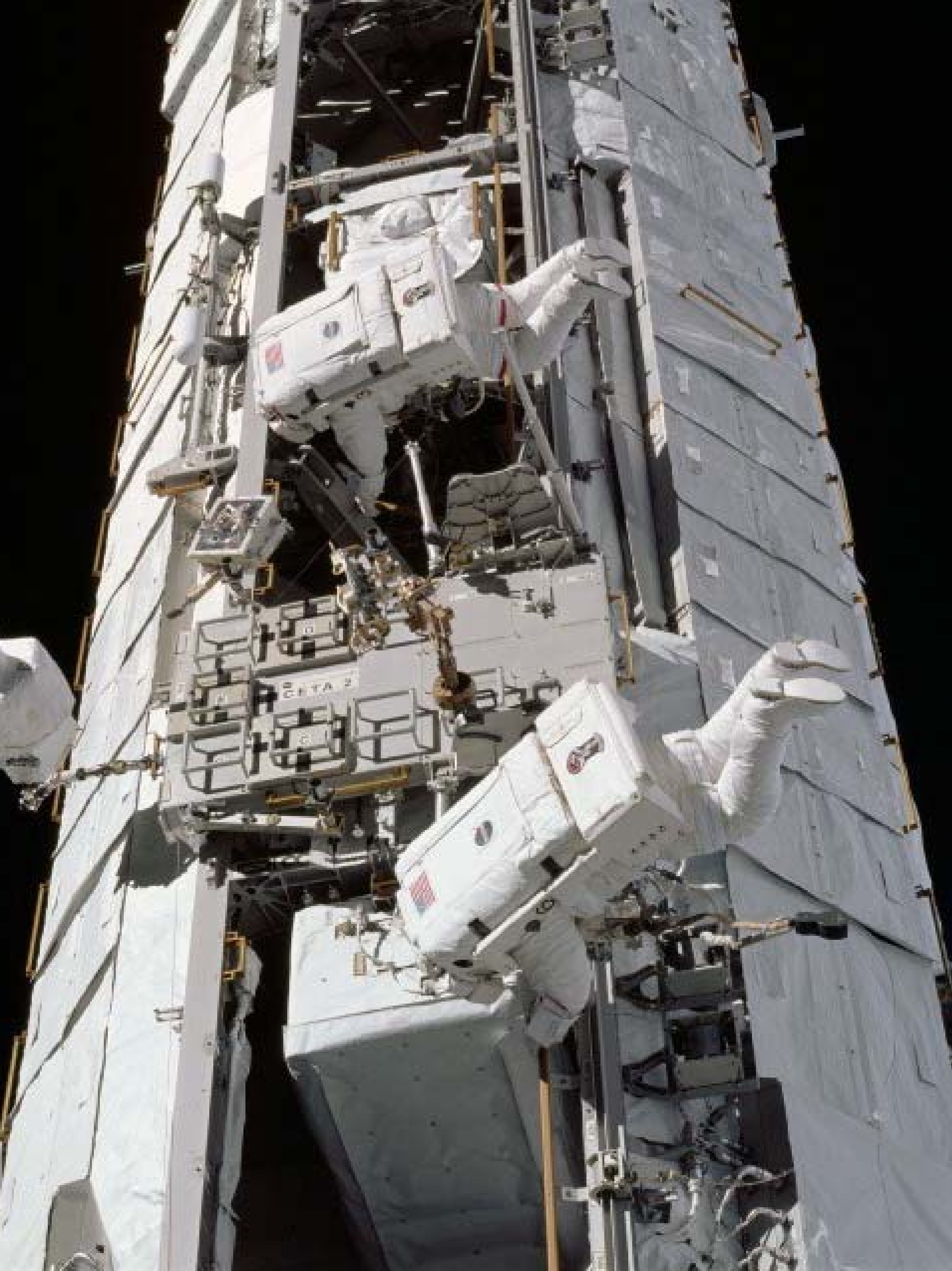
Space Shuttle Atlantis ACCESS EVA
NASA Langley Research Center 2/26/1986 Image # EL-1996-00066



INTERNATIONAL
SPACE STATION
A New Star On the Horizon!
Science Power Platform
Service Module
Life Support Module
Docking Compartment
Universal Docking Module
Control Module (Zarya/Sunrise)
Pressurized Mating Adaptor 1
Research Module
Soyuz
Research Module
FGB Derived Module
Soyuz
Thermal Control Panels
S0 Truss Segment
Mobile Transporter
P3 Truss Segment
Solar Alpha Rotary Joint
P5 Truss Segment
P6 Truss Segment
Port Photovoltaic Arrays
S3 Truss Segment
S6 Truss Segment
S5 Truss Segment
Starboard Photovoltaic Arrays
S4 Truss Segment
Solar Alpha Rotary Joint
S1 Truss Segment
Node 1 (Unity)
CSA Remote Manipulator System
Z1 Truss Segment
P1 Truss Segment
P4 Truss Segment
Cupola
Airlock
Centrifuge Accommodations Module
JEM Experiment Logistics Module
JEM Remote Manipulator System
JEM Exposed Facility
Japanese Experimental Module (JEM)
U.S. Lab
ESA Lab
Node 2
Node 3
Habitation Module
Crew Return Vehicle
Pressurized Mating Adaptor 2
Pressurized Mating Adaptor 3
United States
Russia
Japan
Europe
Canada
Brazil
BOEING

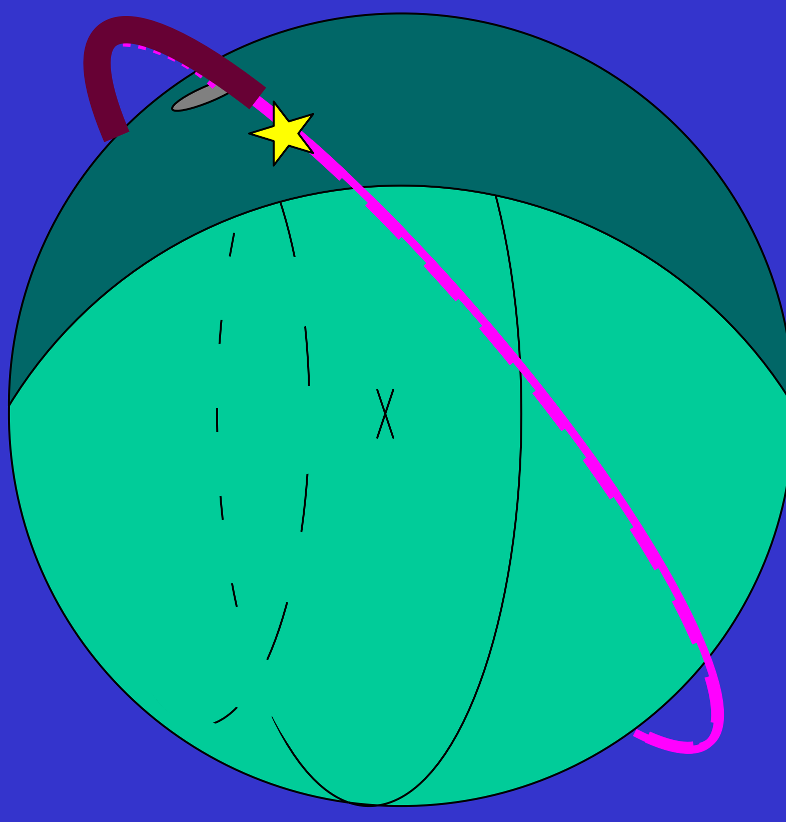

Pitch In!
GOOD HOUSEKEEPING MAKES OUR JOBS SAFER



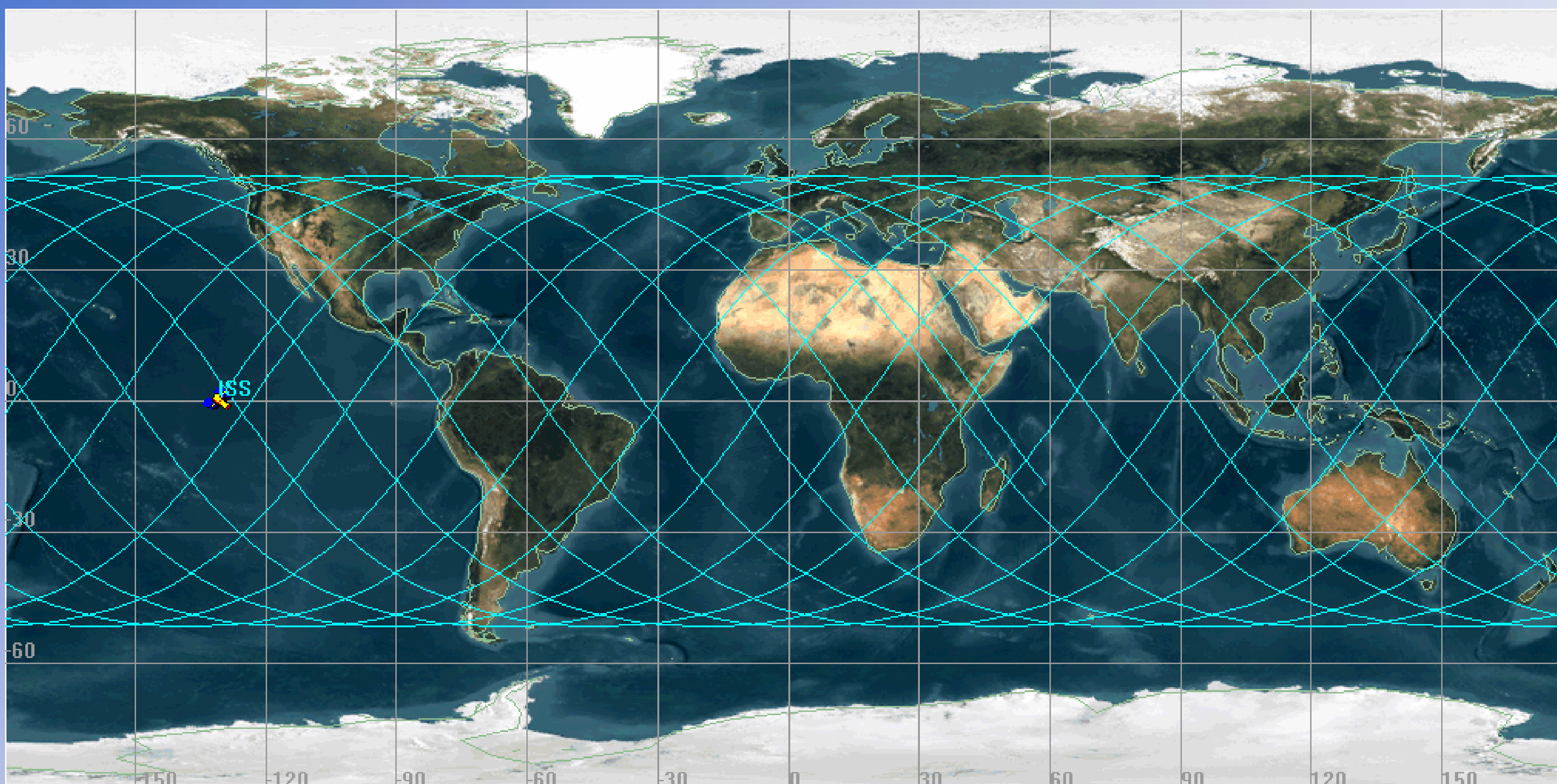

CETA 2

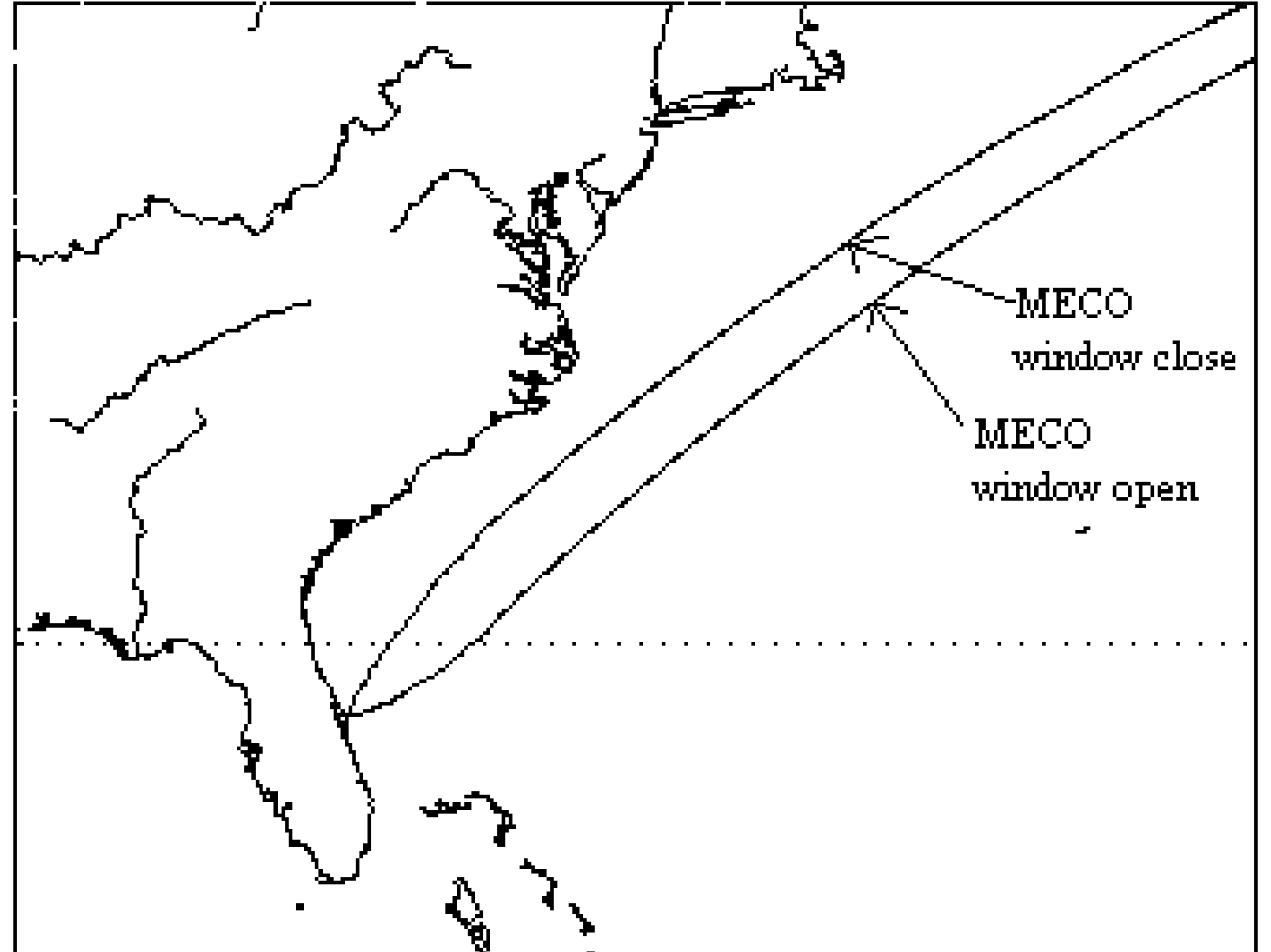
Meeting Up There:

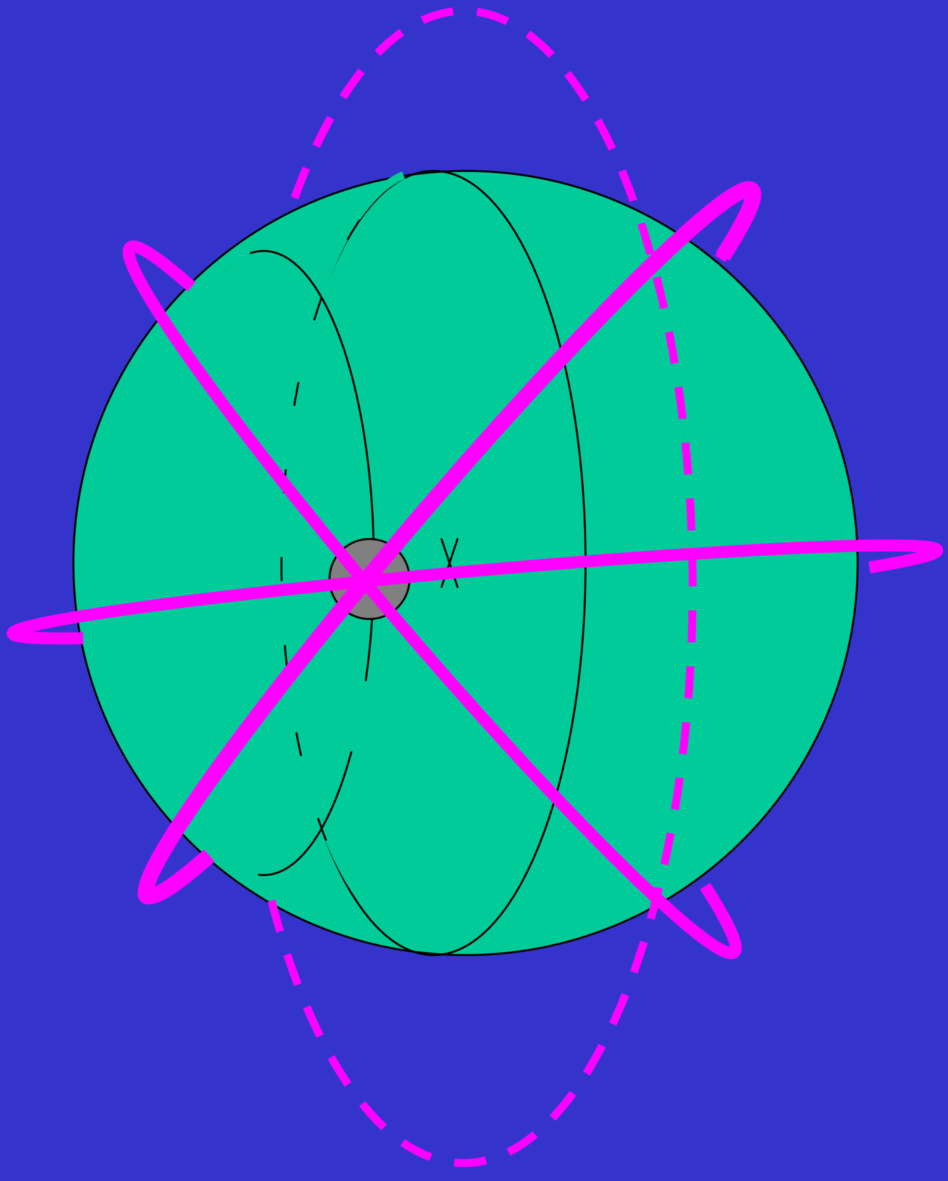
(Dancing to the music of the celestial spheres)

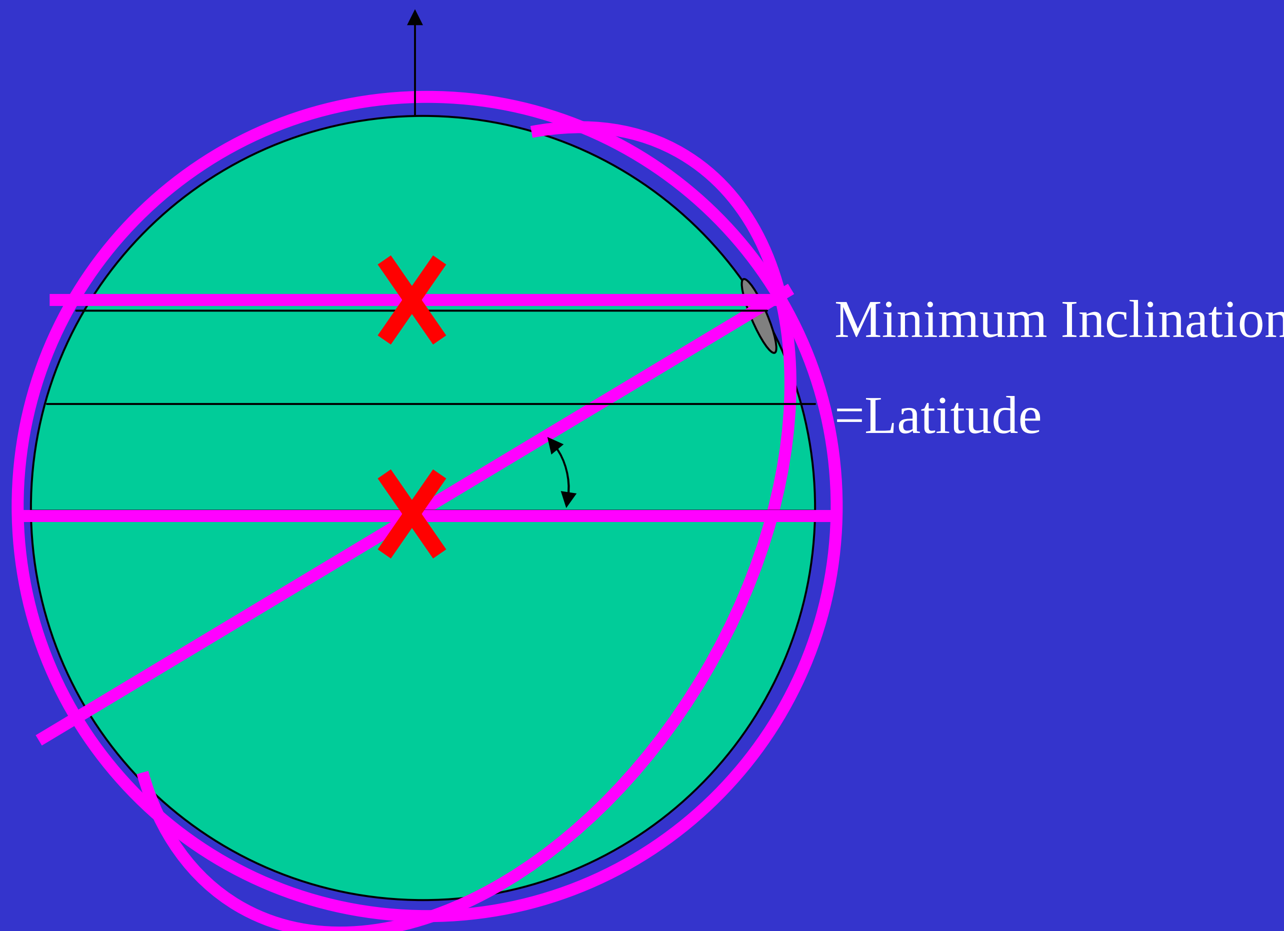


ISS Ground Track

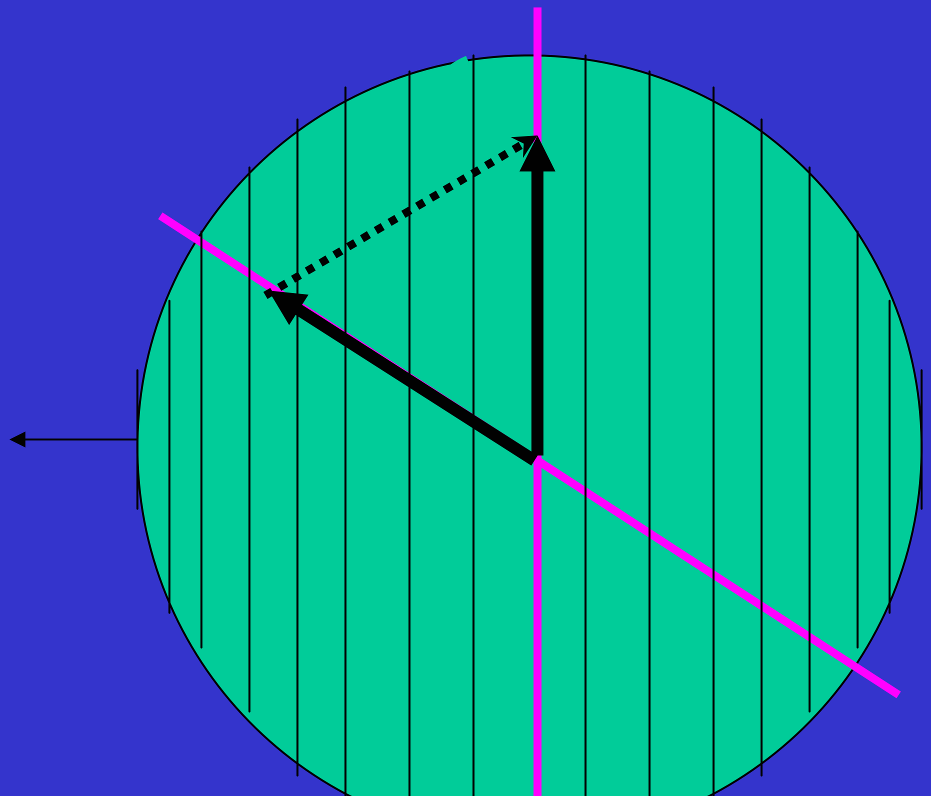



MECO
window close
MECO
window open



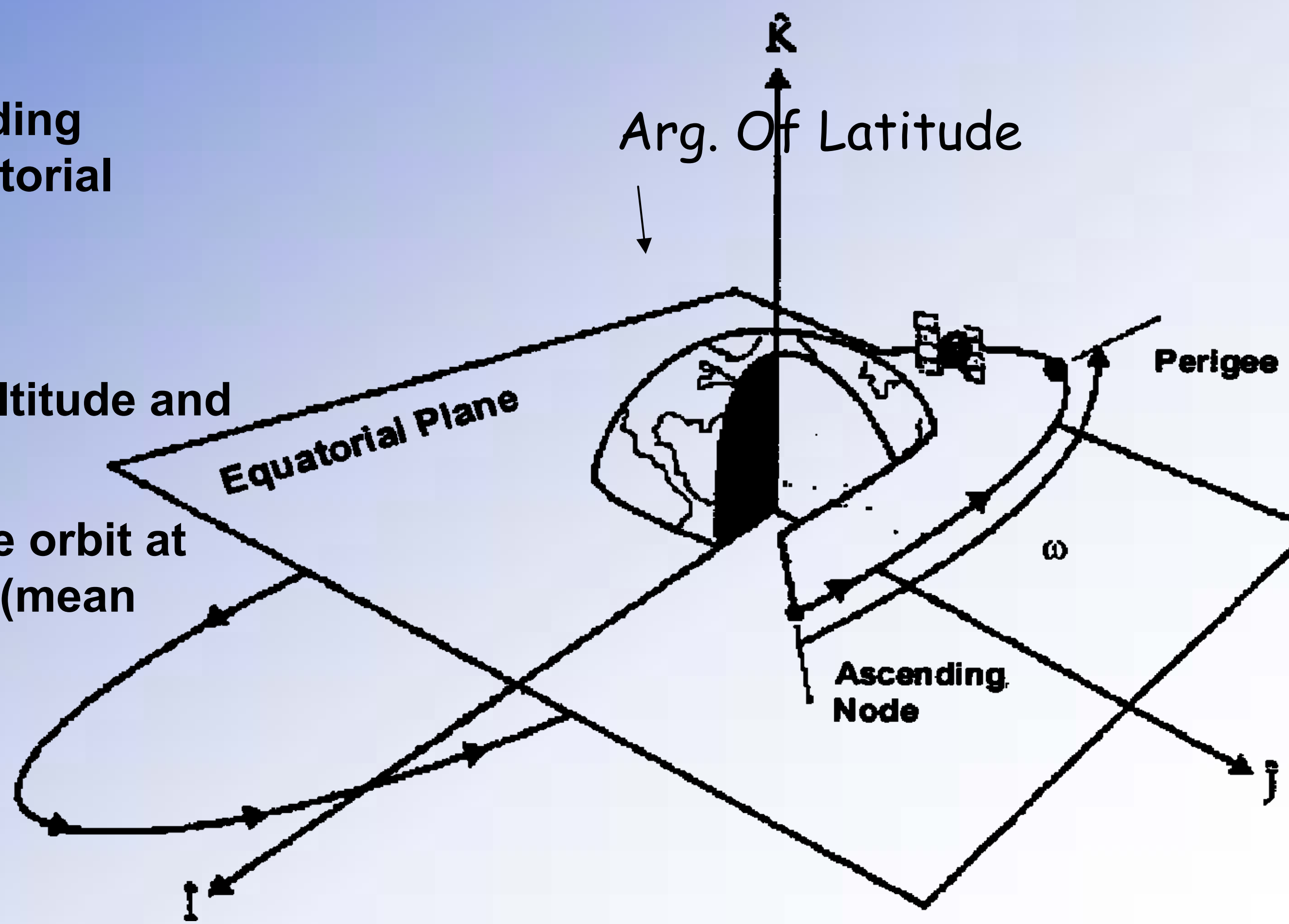


Minimum Inclination
=Latitude

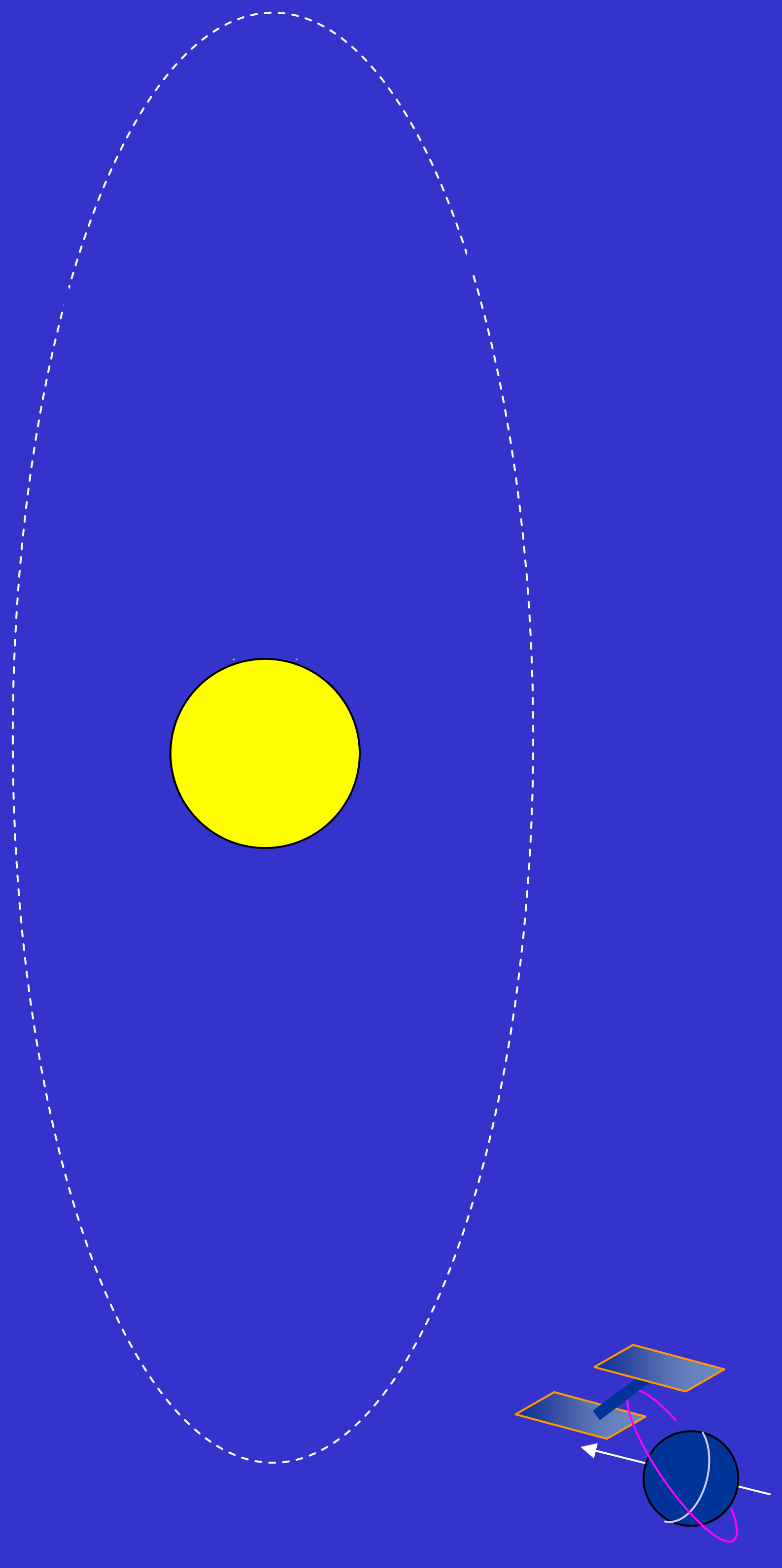


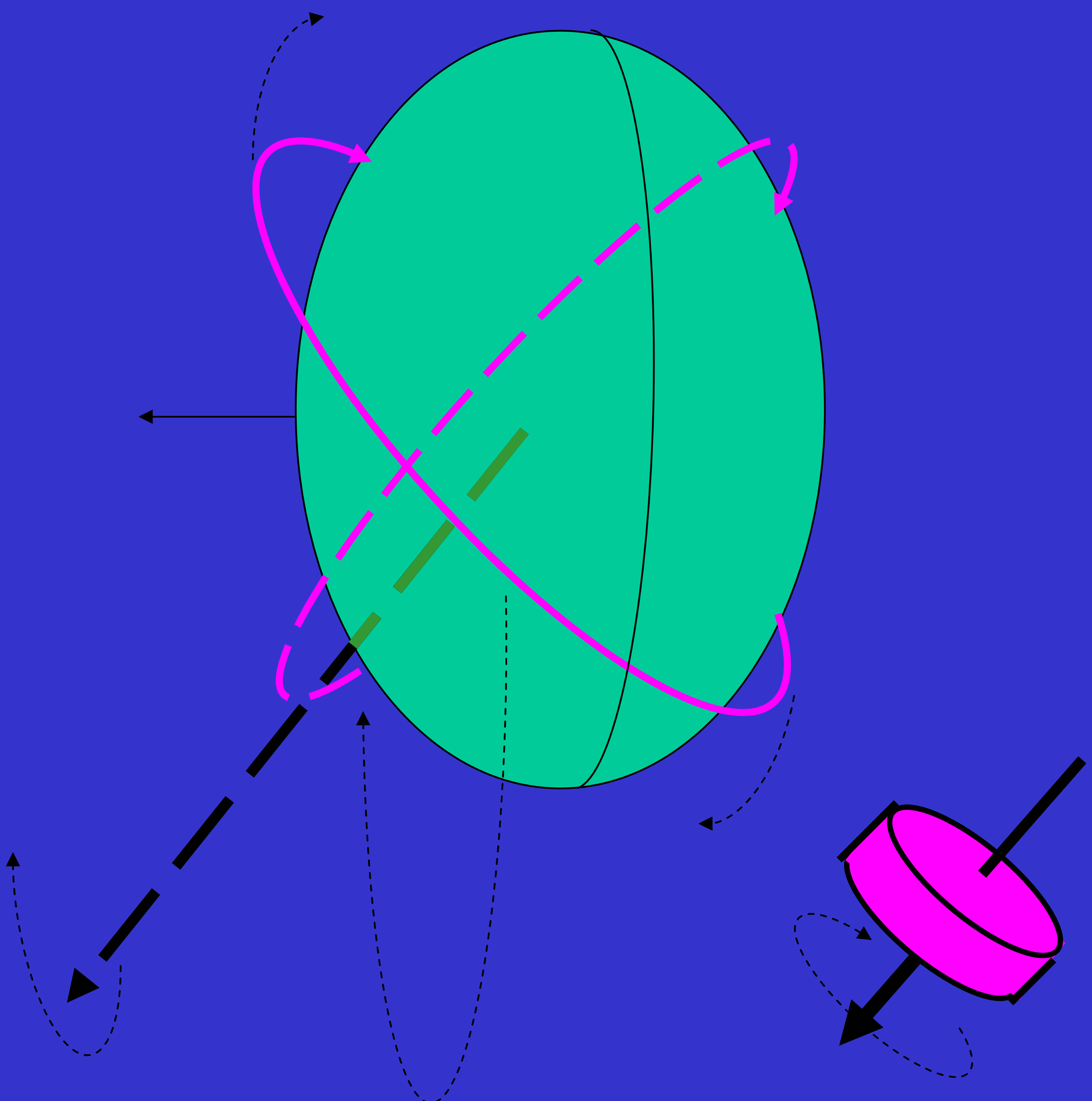
Orbit Parameters (6 needed)

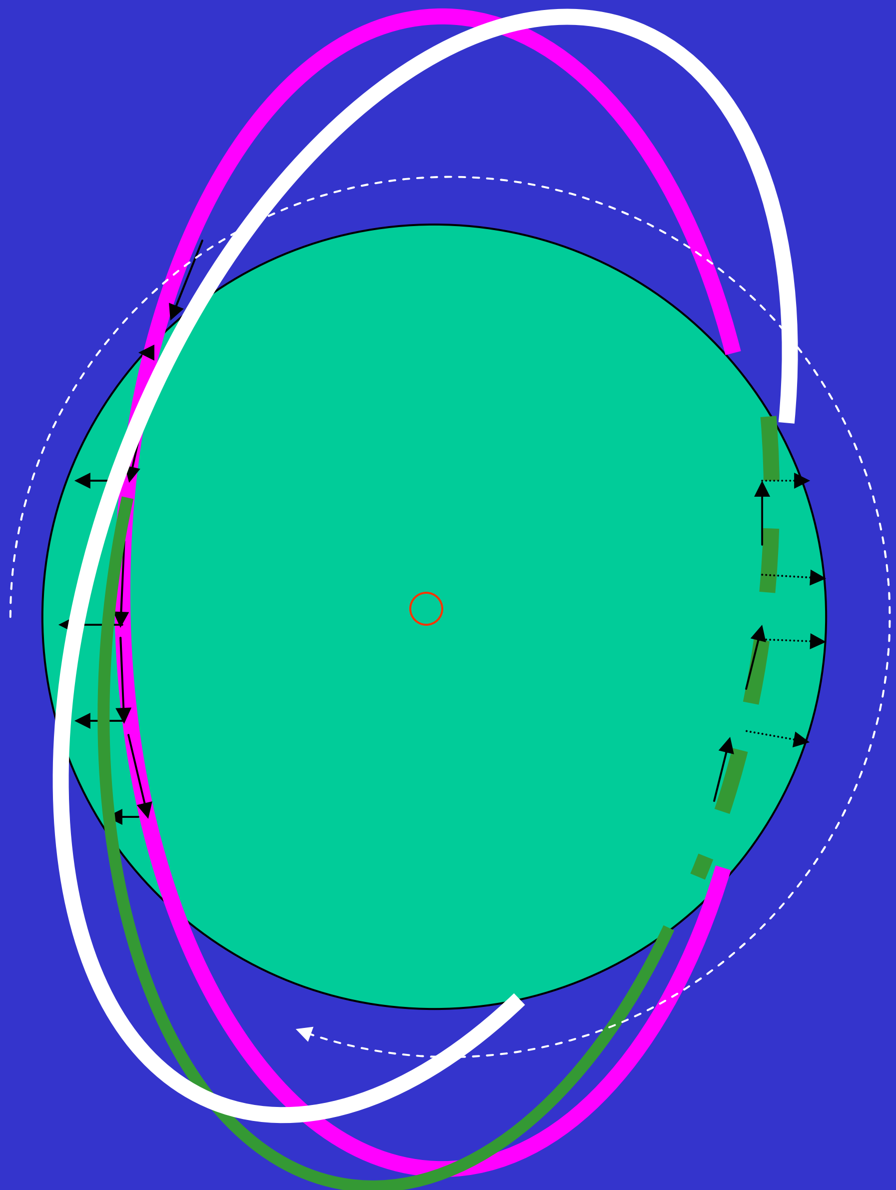
1. Time (t)
2. Inclination (i)
3. Location of Ascending (North-going) equatorial crossing (RAAN)
4. Apogee
5. Perigee (or mean altitude and eccentricity)
6. Angle ω around the orbit at the specified time. (mean anomaly)



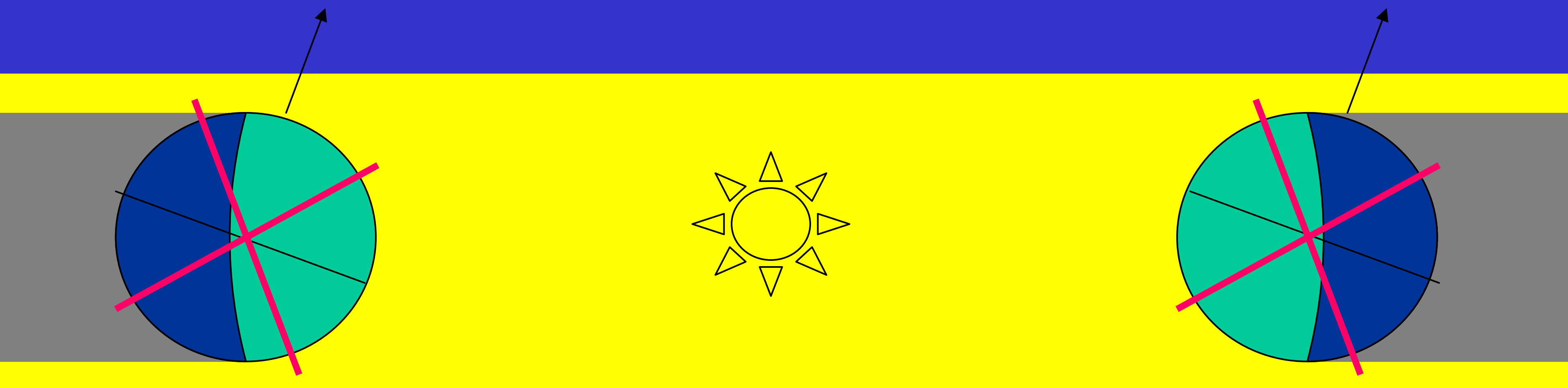
Subtle things that can getcha:
The Beta Angle

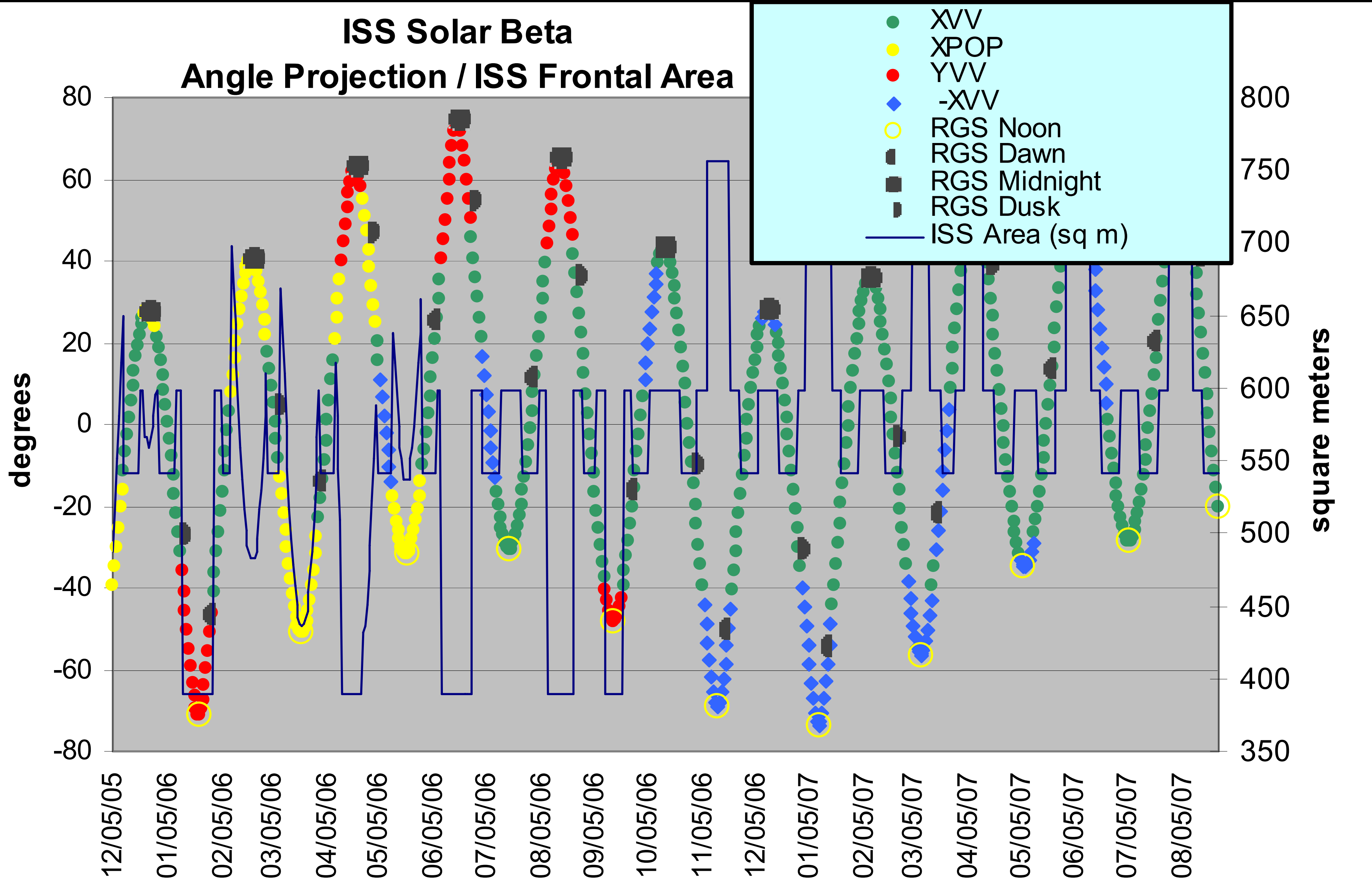






It all adds up:




ISS Solar Beta
Angle Projection / ISS Frontal Area
XVV
XPOP
YVV
-XVV
RGS Noon
RGS Dawn
RGS Midnight
RGS Dusk
ISS Area (sq m)
degrees
square meters
80
60
40
20
0
-20
-40
-60
-80
800
750
700
650
600
550
500
450
400
350
12/05/05
01/05/06
02/05/06
03/05/06
04/05/06
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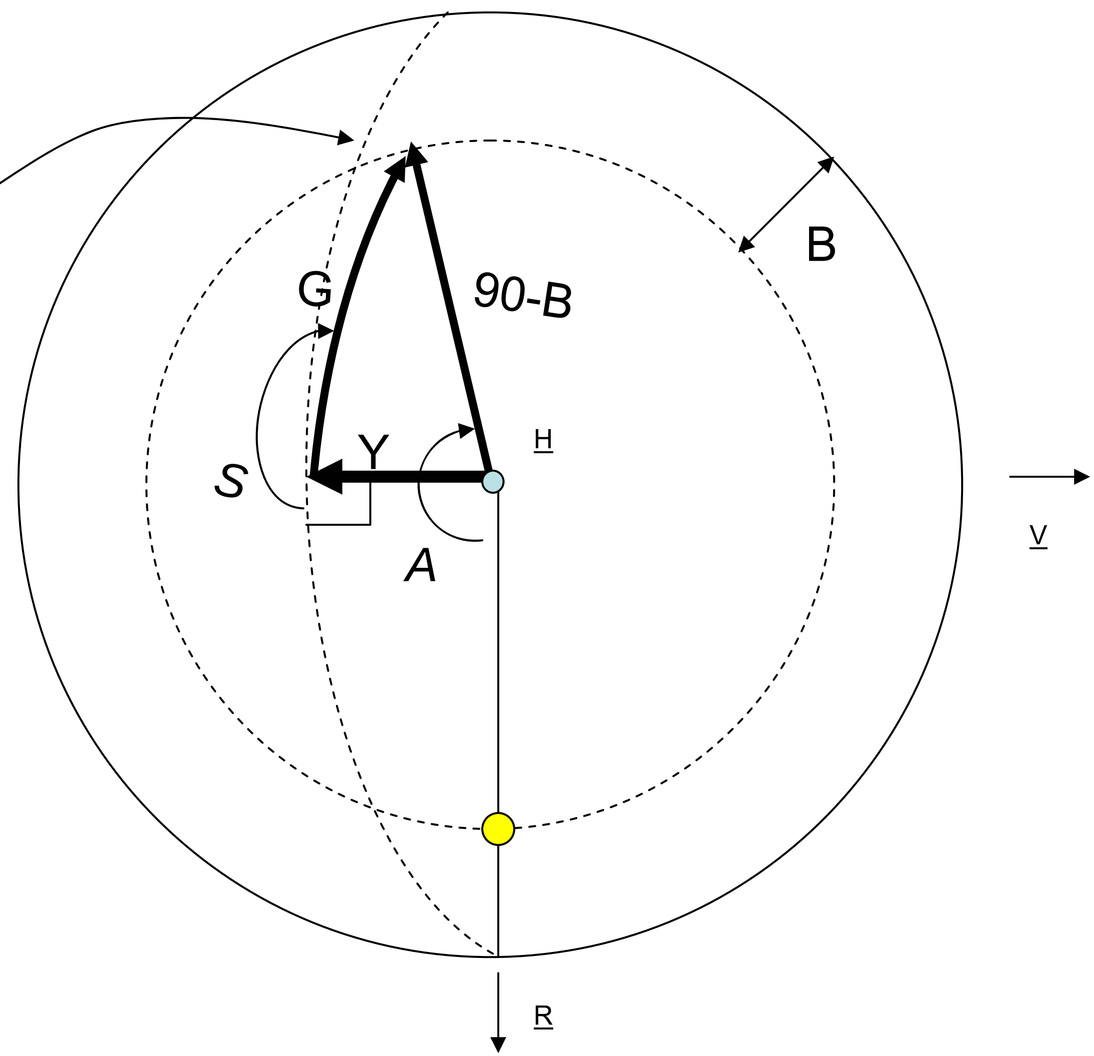
03/05/07
04/05/07
05/05/07
06/05/07
07/05/07
08/05/07

So we use a lot of SPHERICAL GEOMETRY…

(Great circle meridian through ISS Y and Z axies)

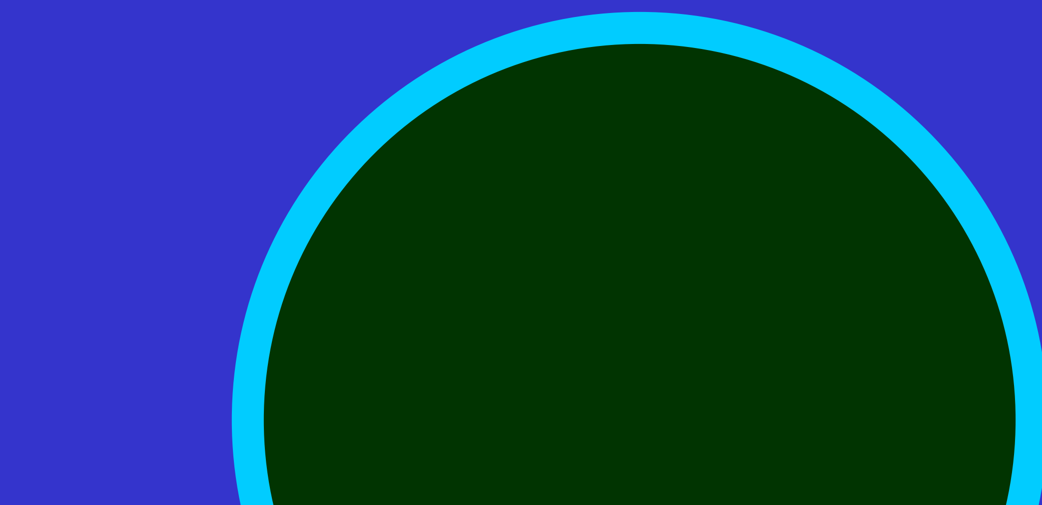


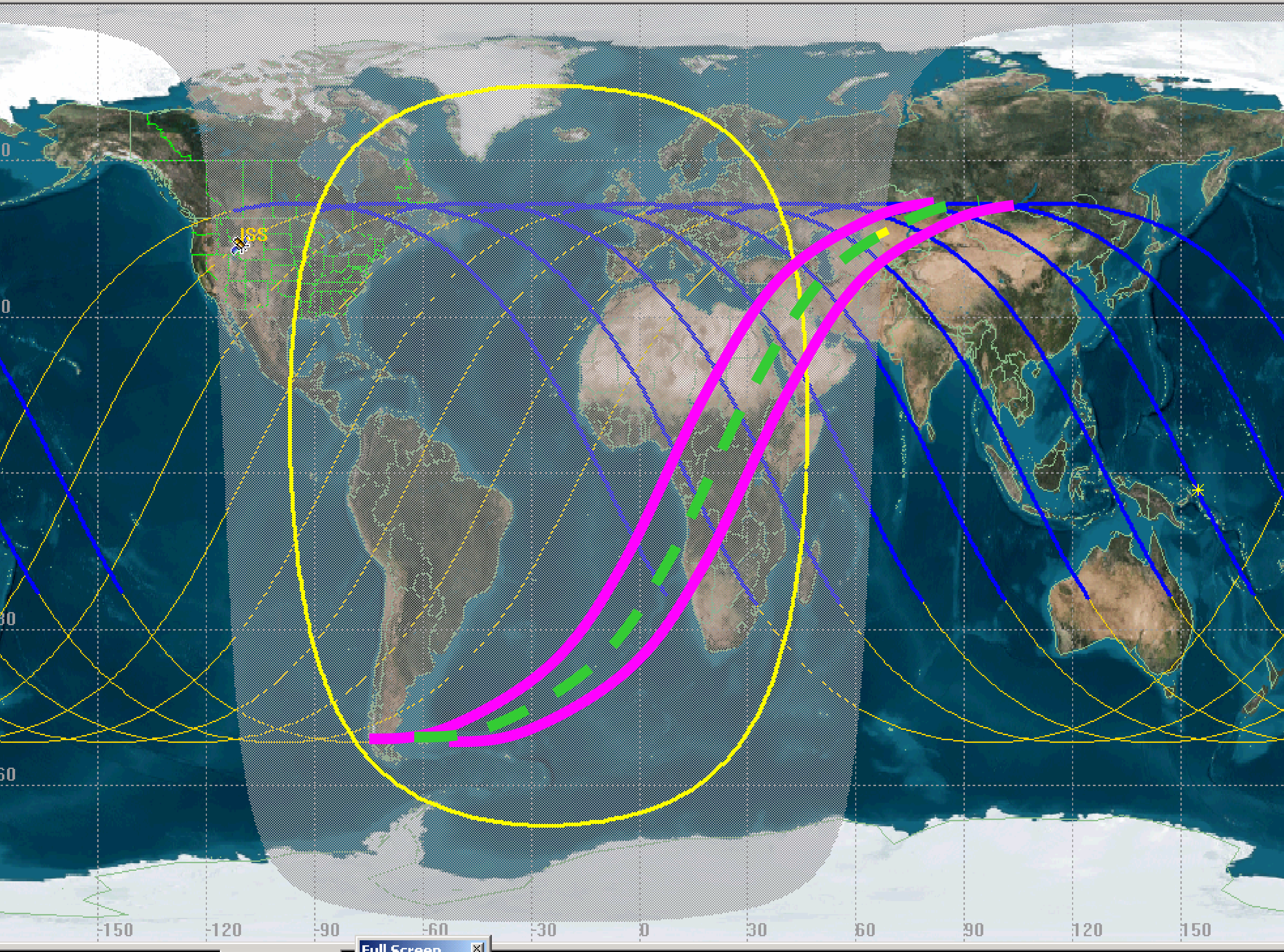
Unit Sphere, centered on spacecraft

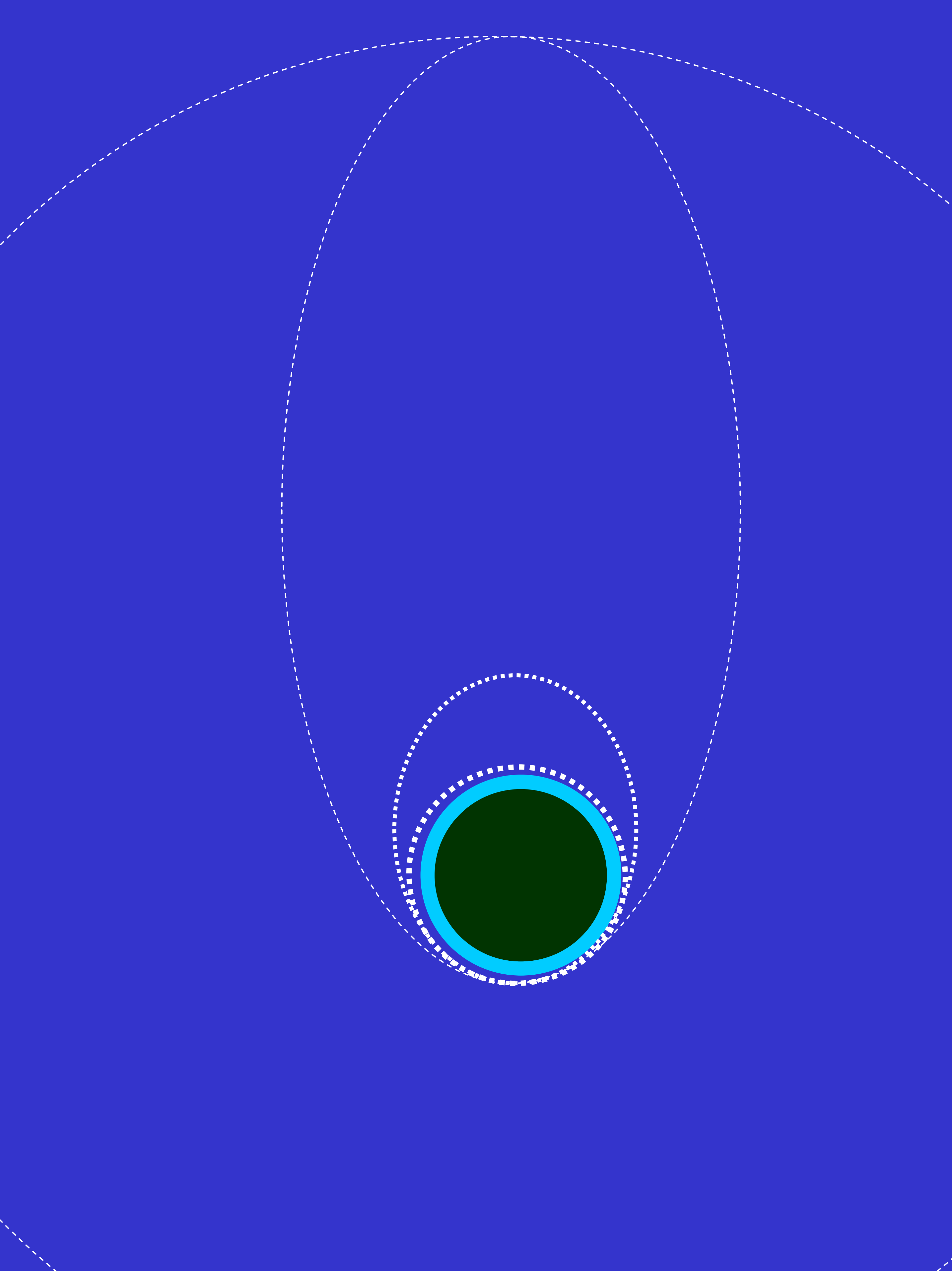
PHASING

Soyuz

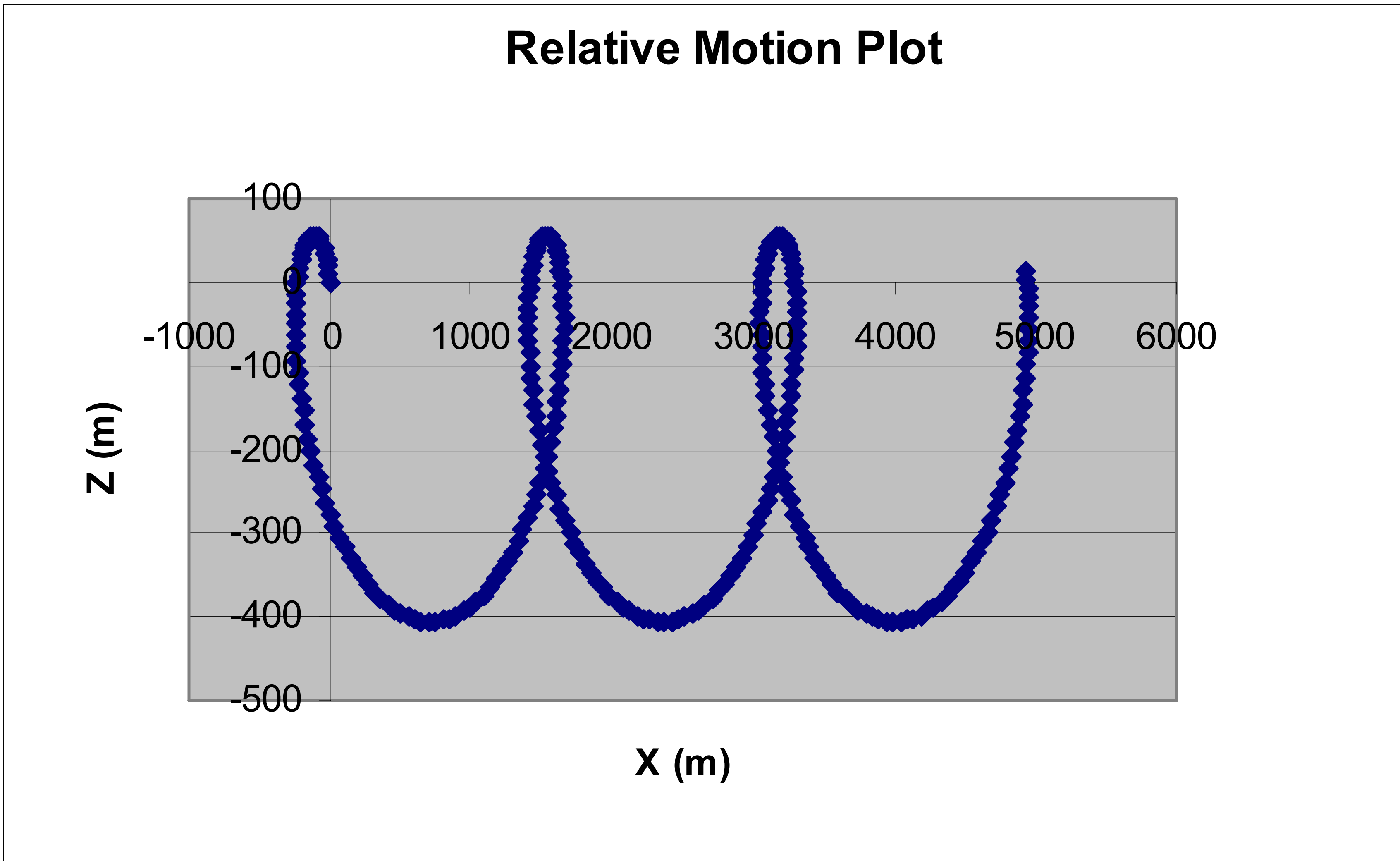
STS FD3

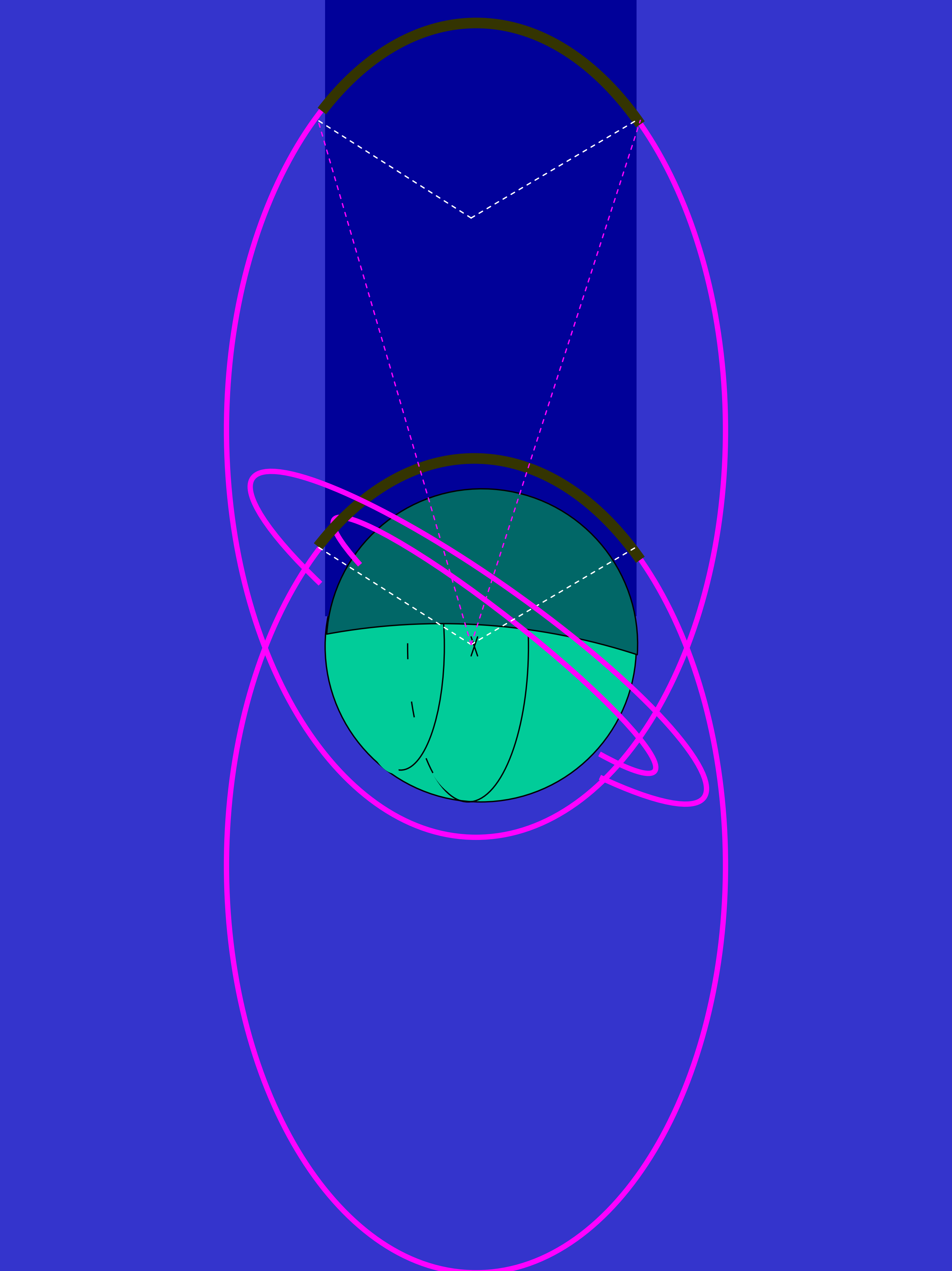



ISS
-150
-120
-90
-60
-30
0
30
60
90
120
150
Full Screen

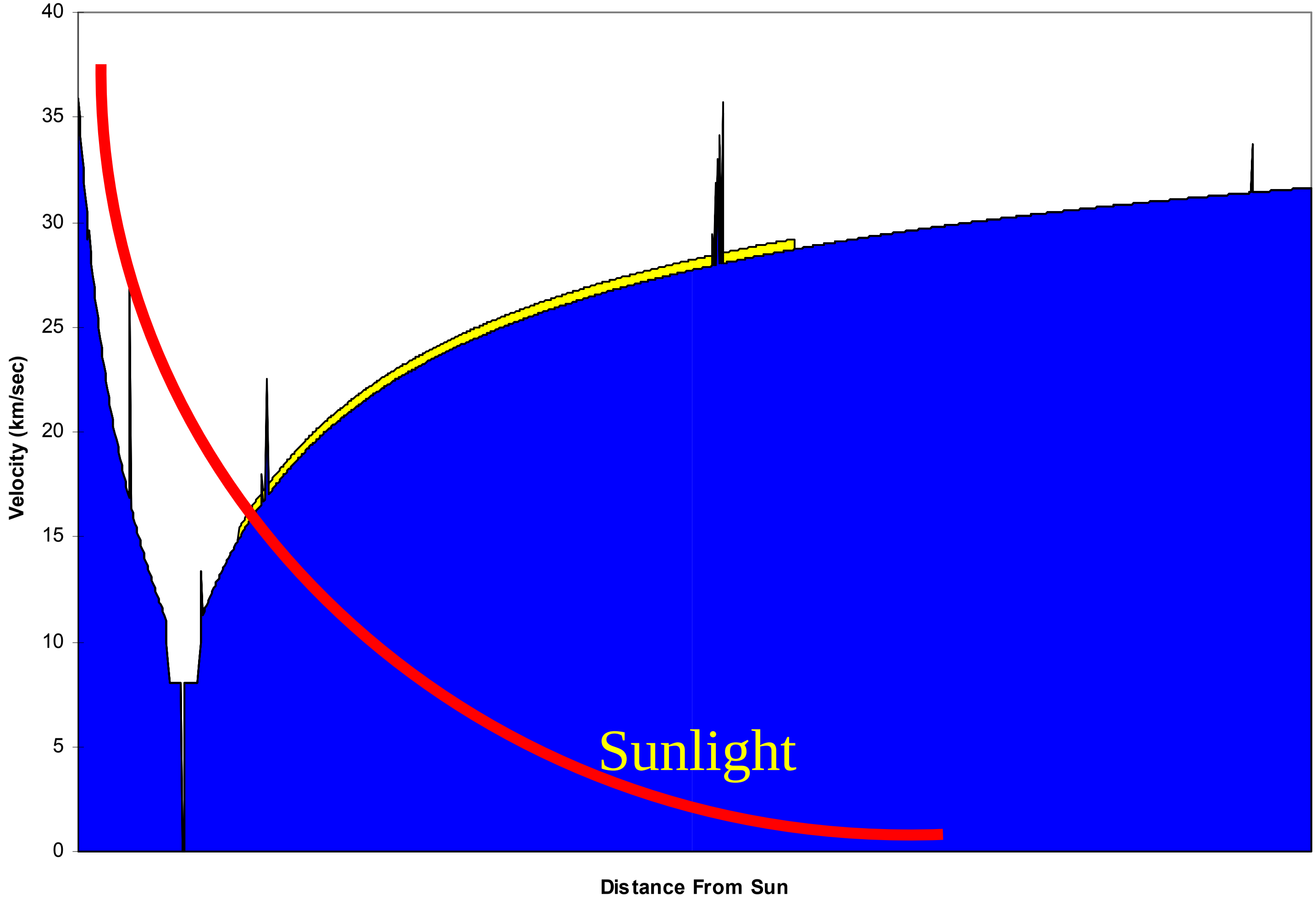


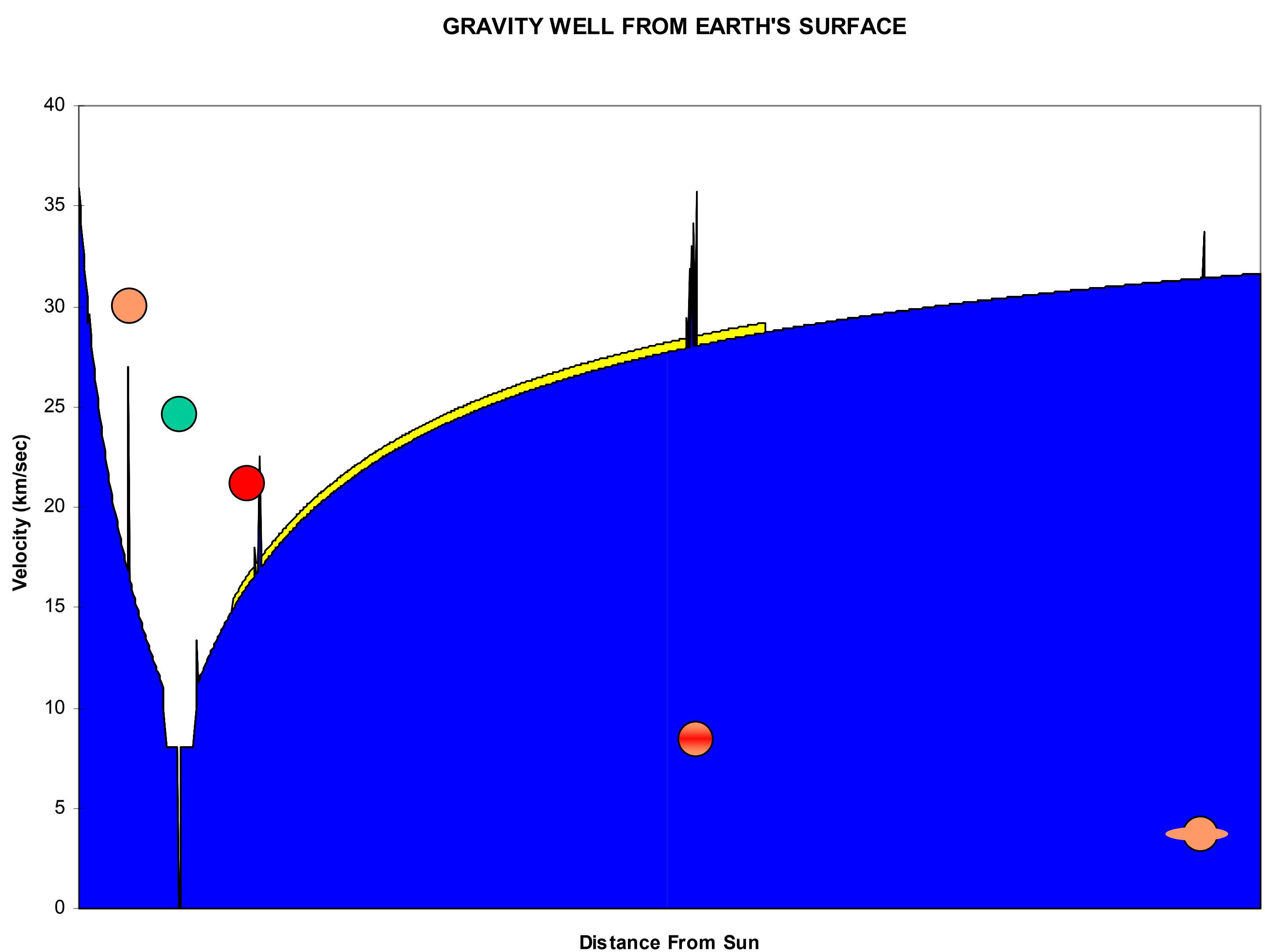
Relative motion is complicated:

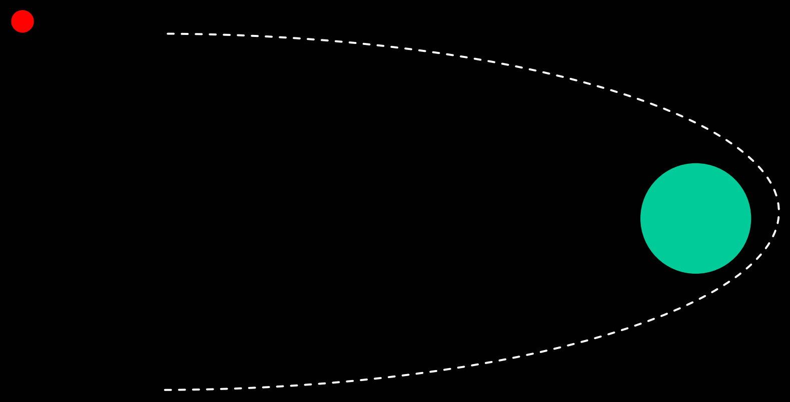


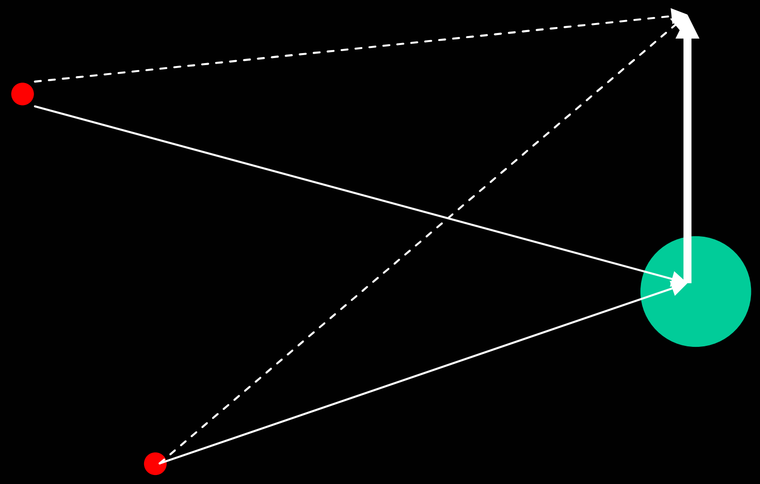


GRAVITY WELL FROM EARTH'S SURFACE

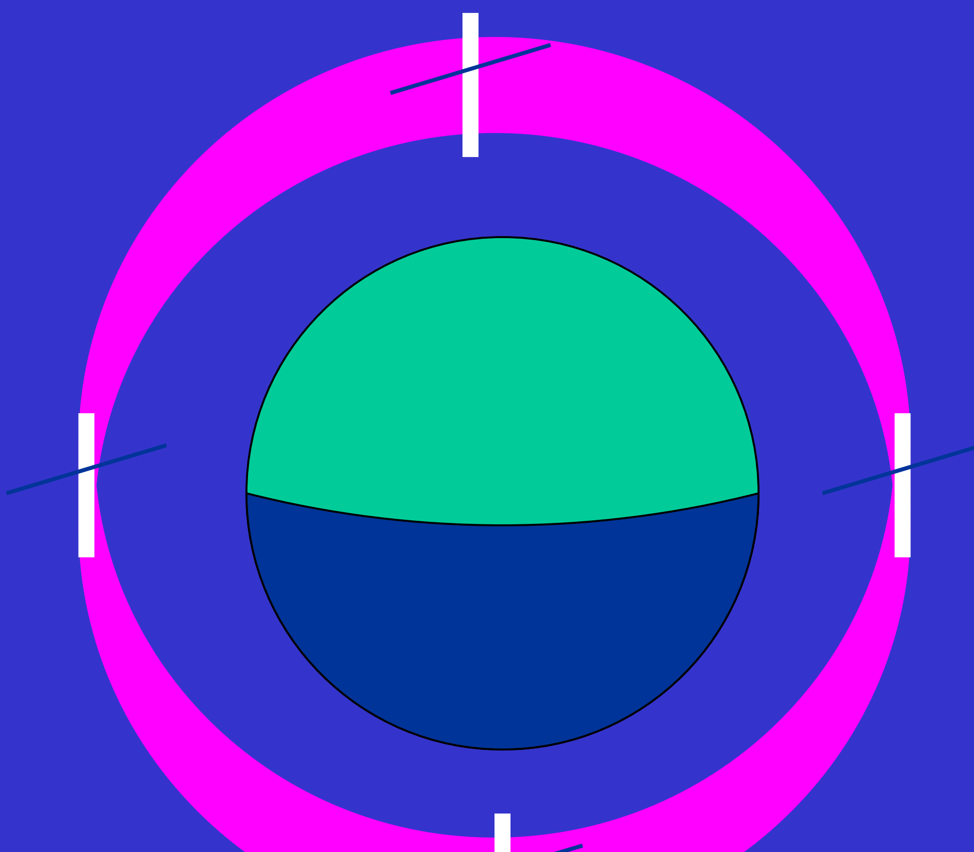


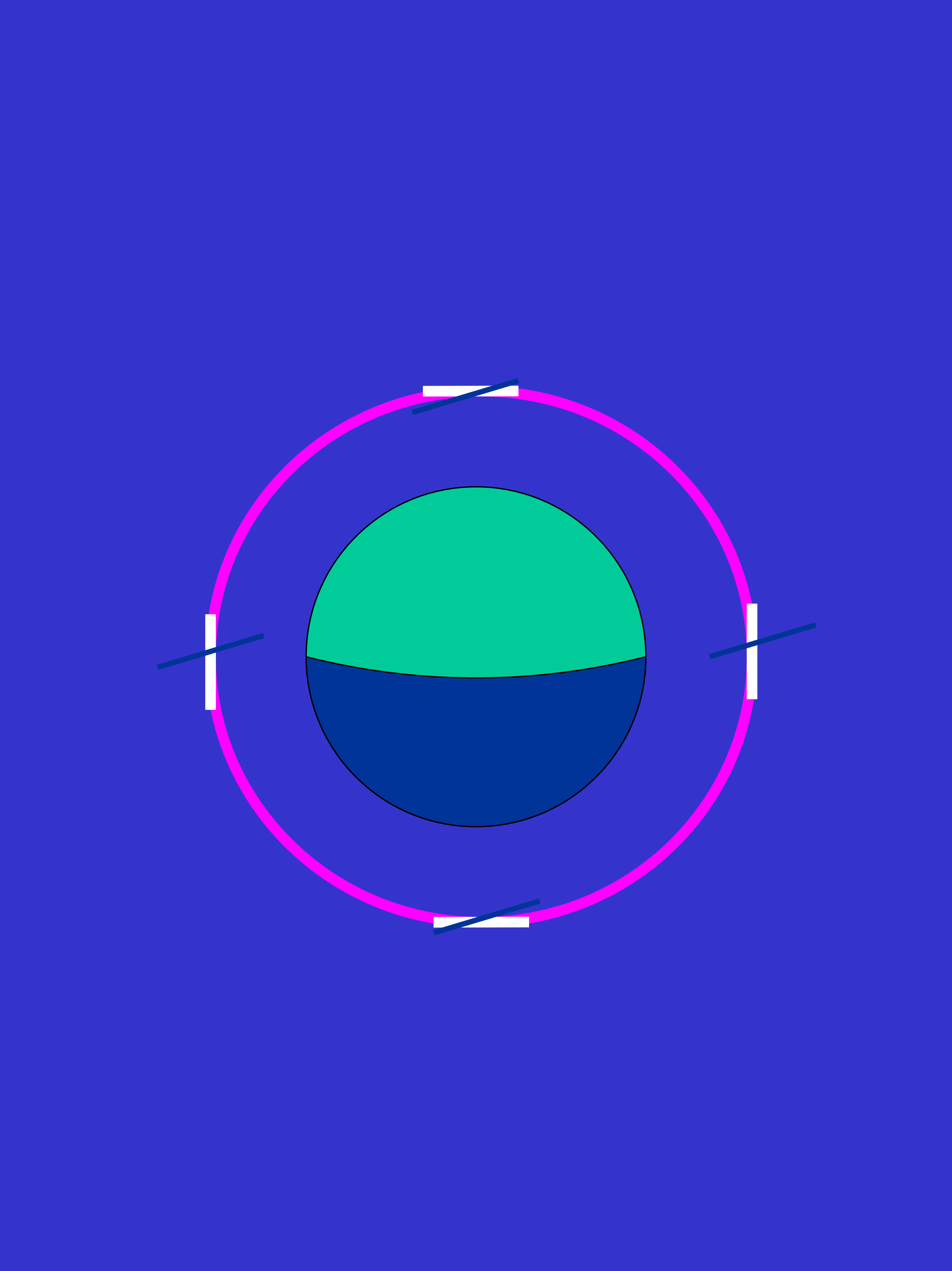

GRAVITY WELL FROM EARTH'S SURFACE
Velocity (km/sec)
40
35
30
25
20
15
10
5
0
Distance From Sun



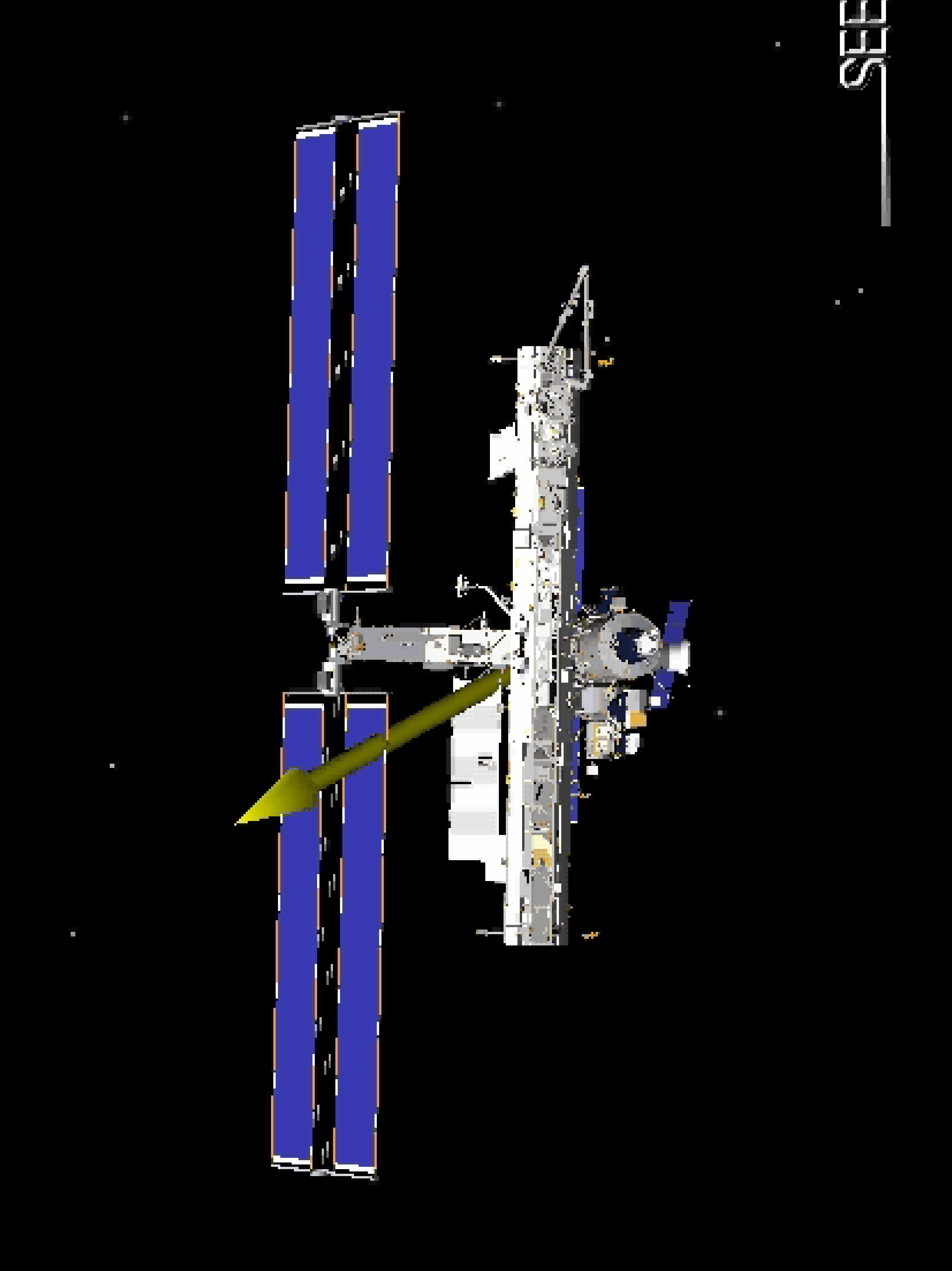


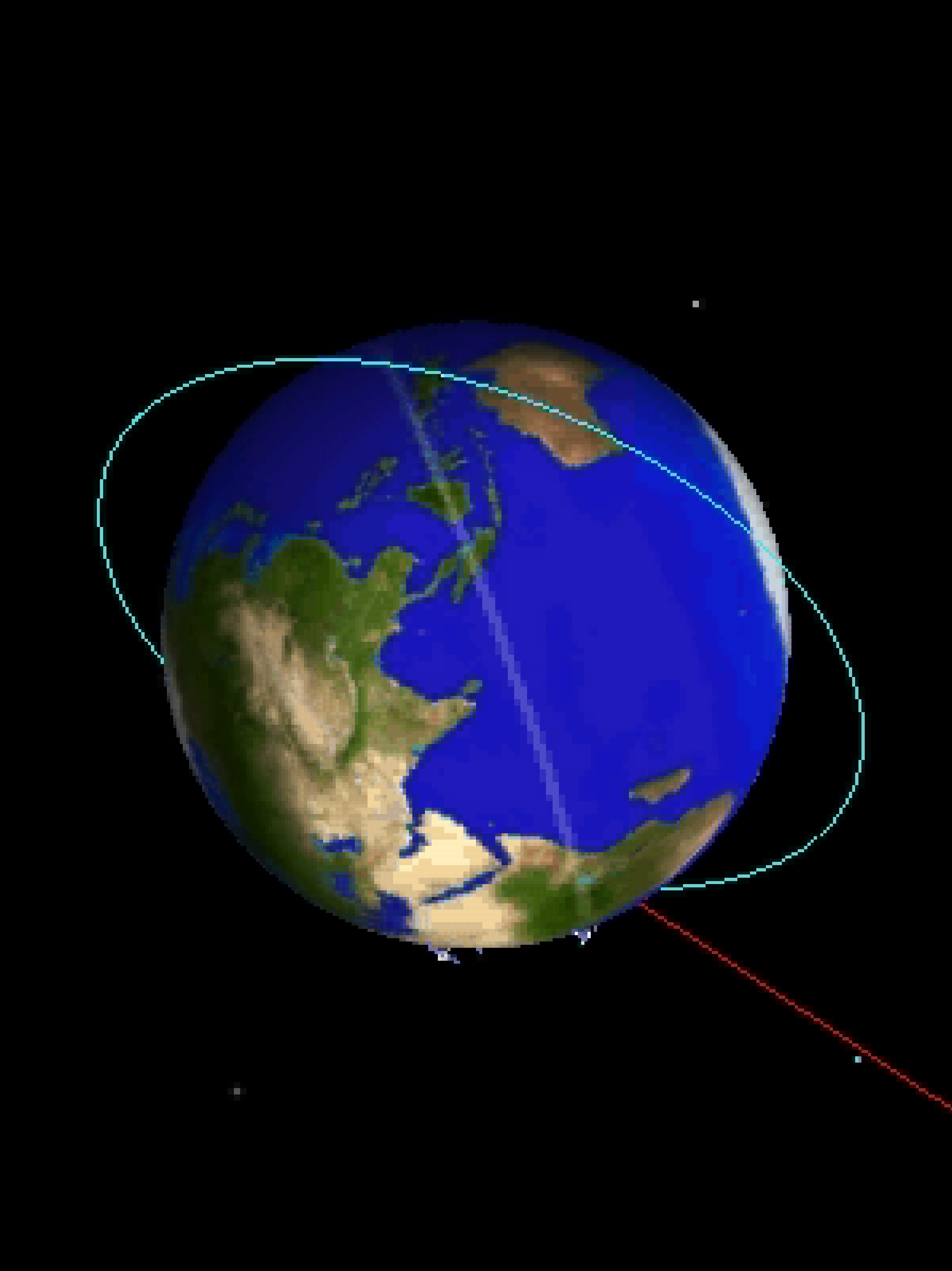
A good Attitude can make your day go better…

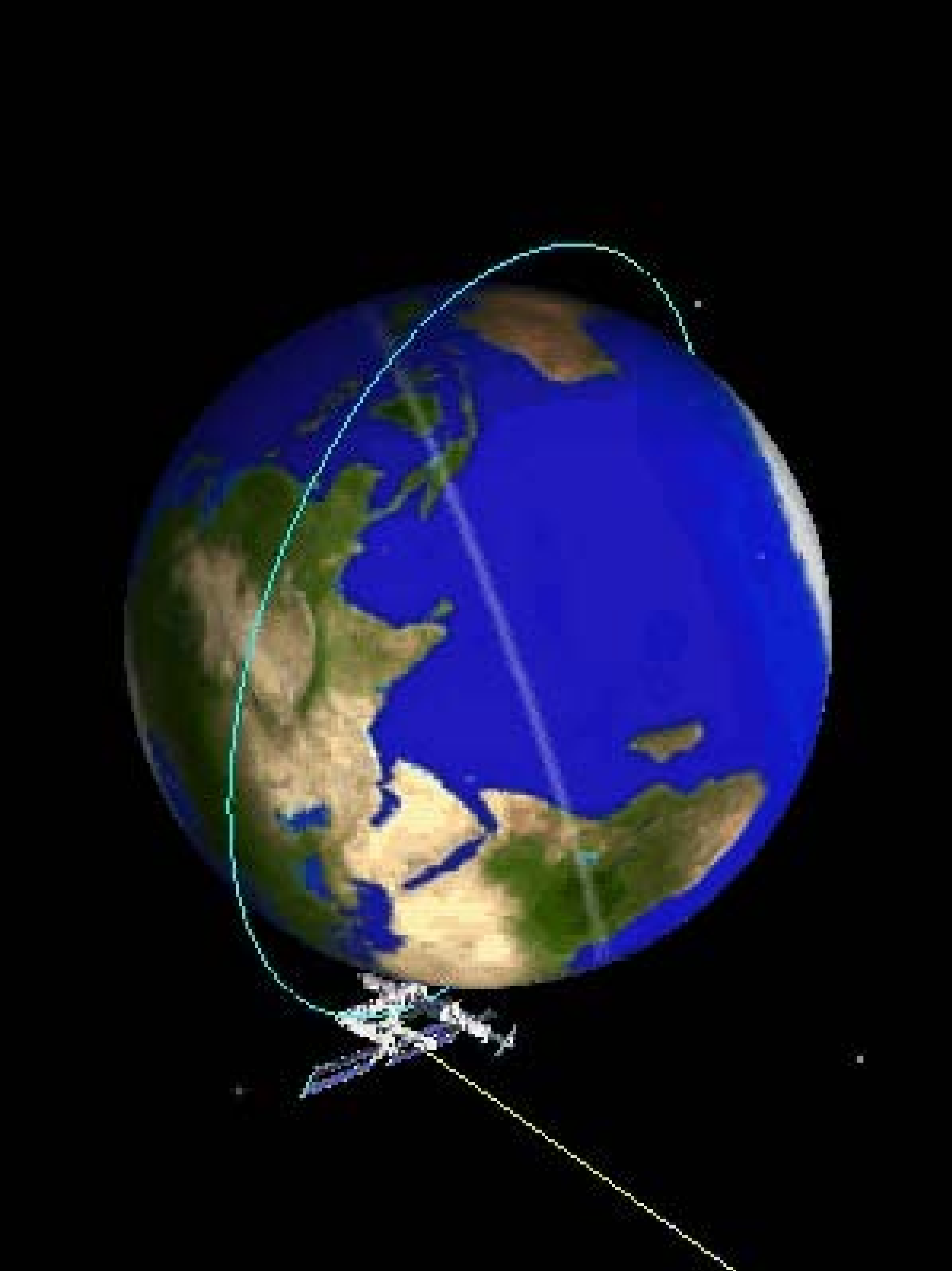


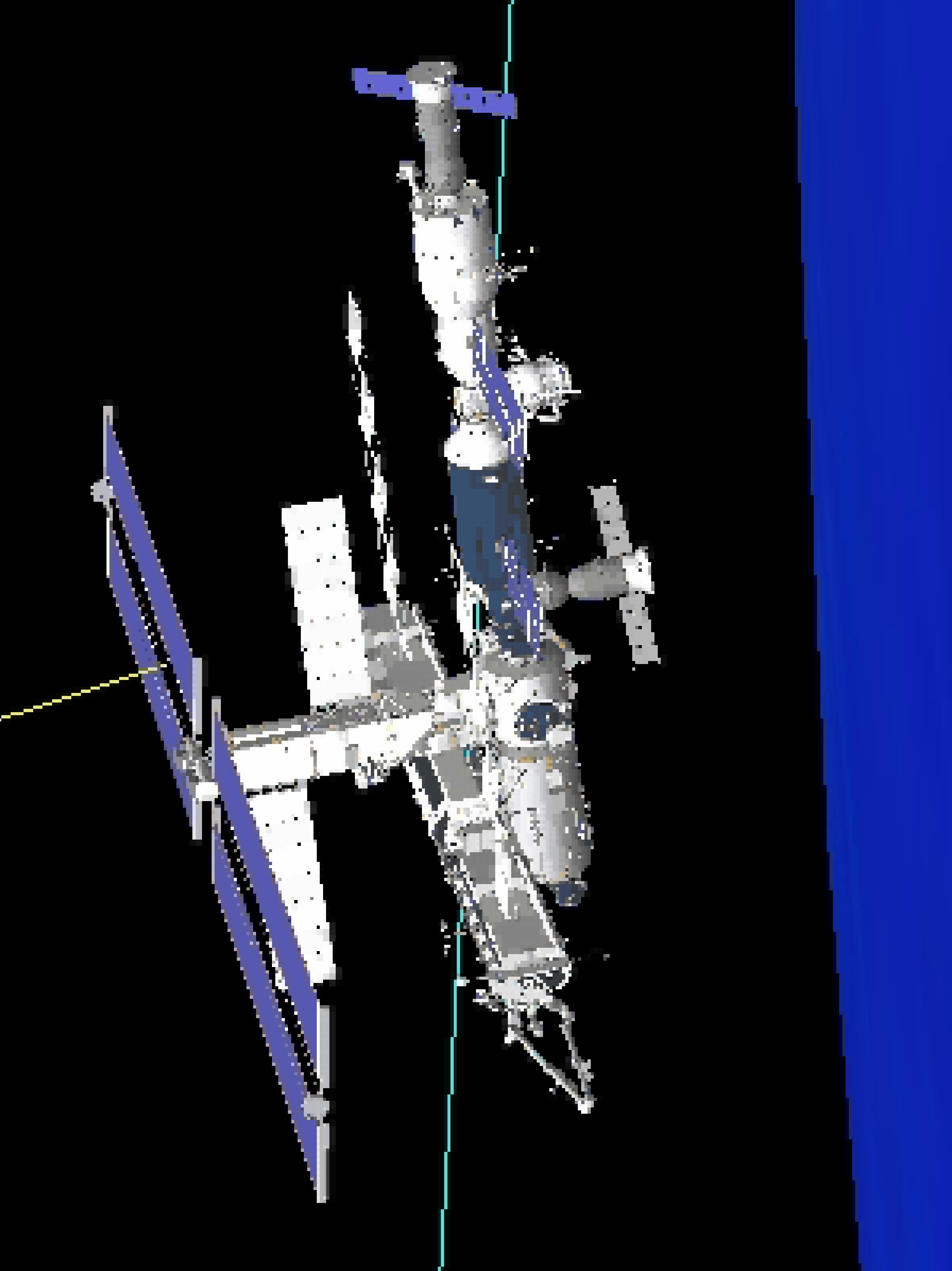


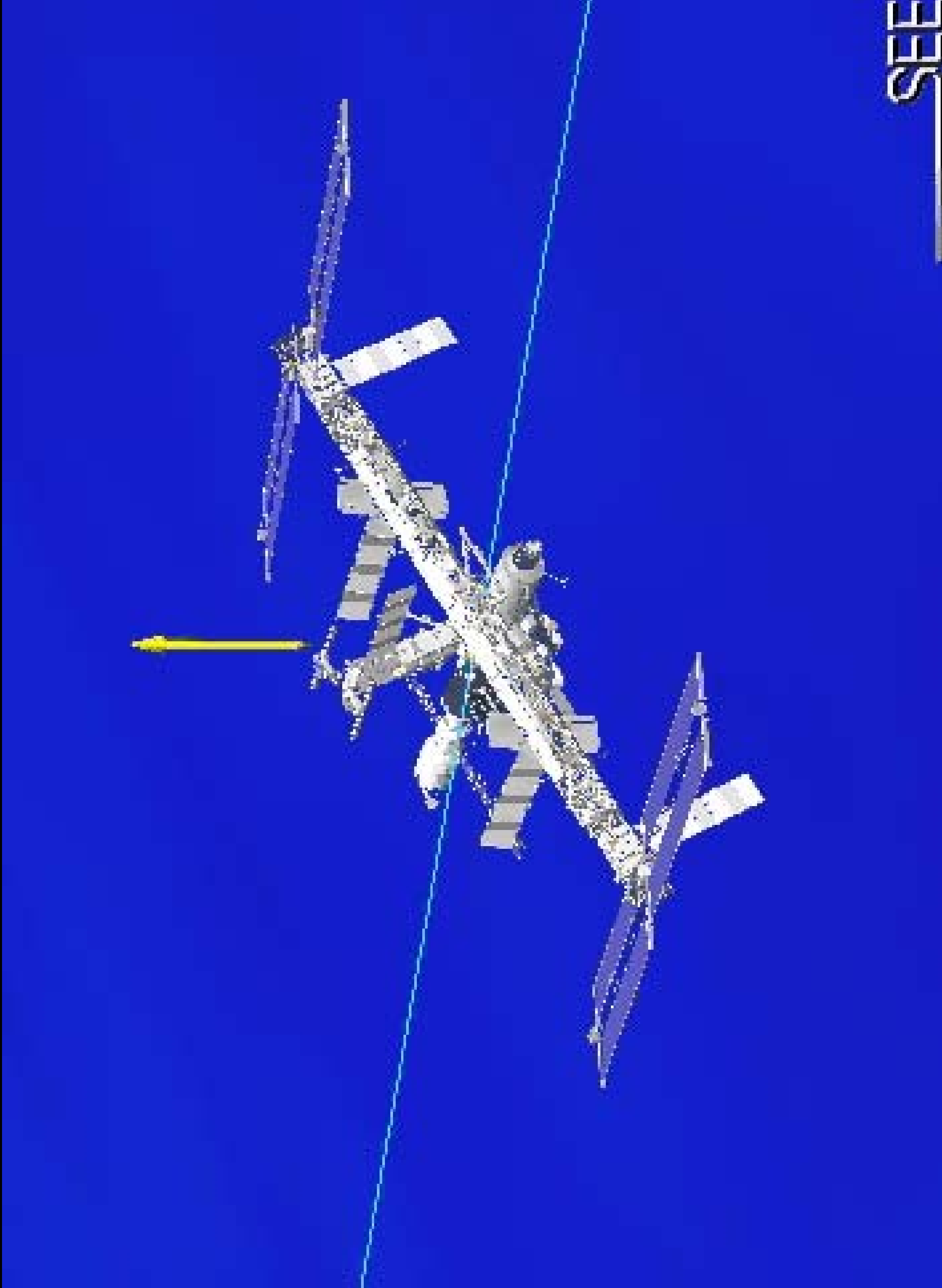

TM STREAM: OK


SEE

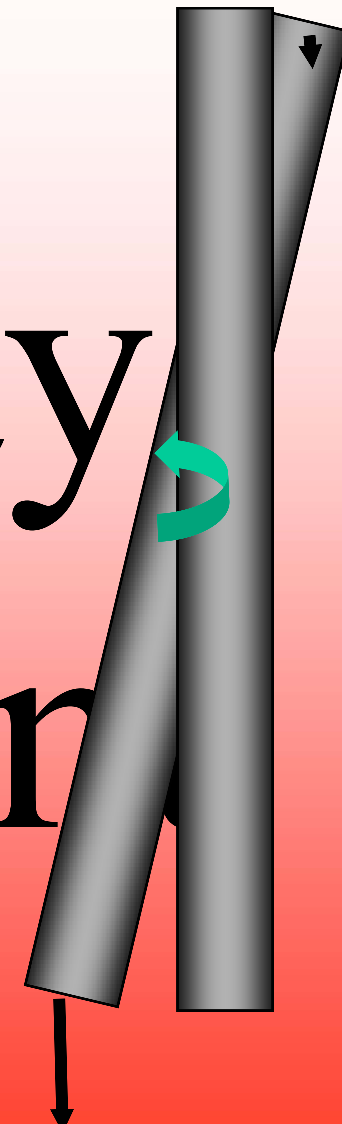




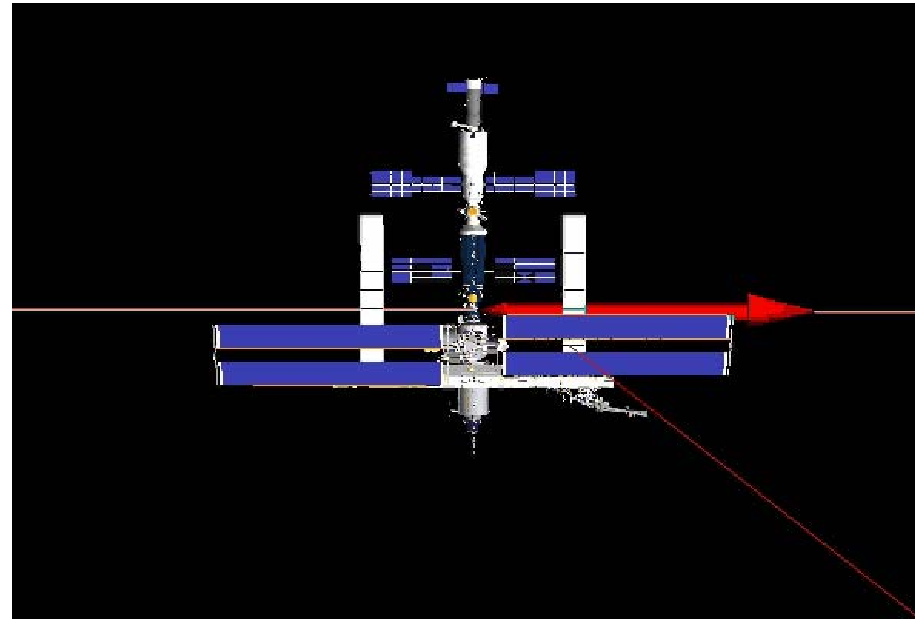


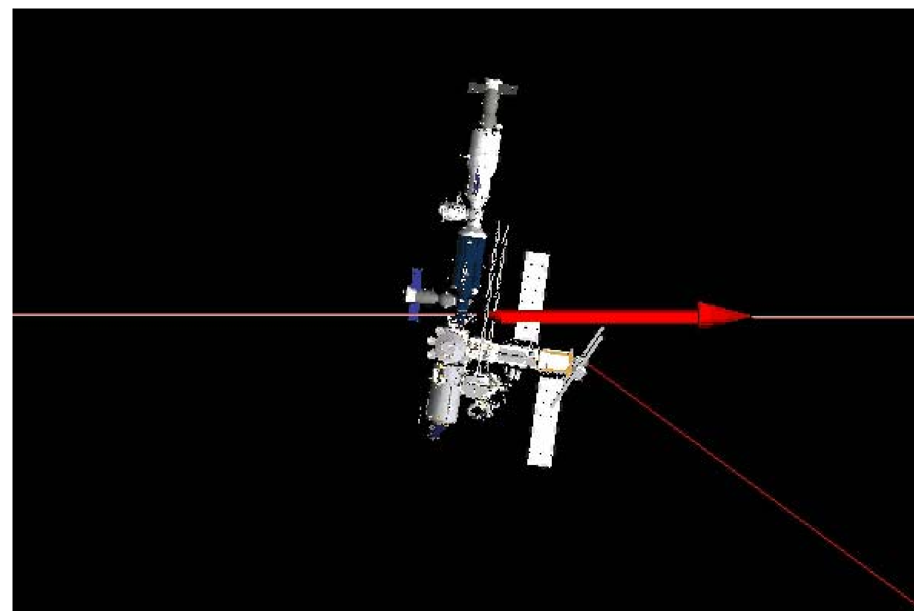


Gravity Gradien



- Gravity Gradient Modes developed
  - Still need thermal certification
  - Emergency option would save propellant if we lose more CMGs

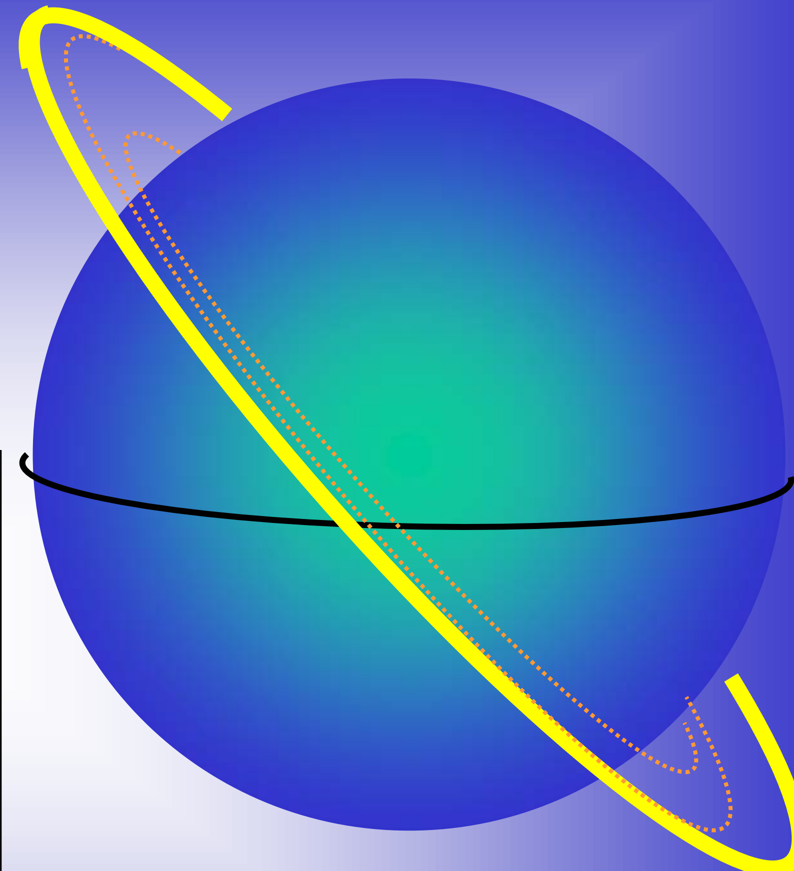


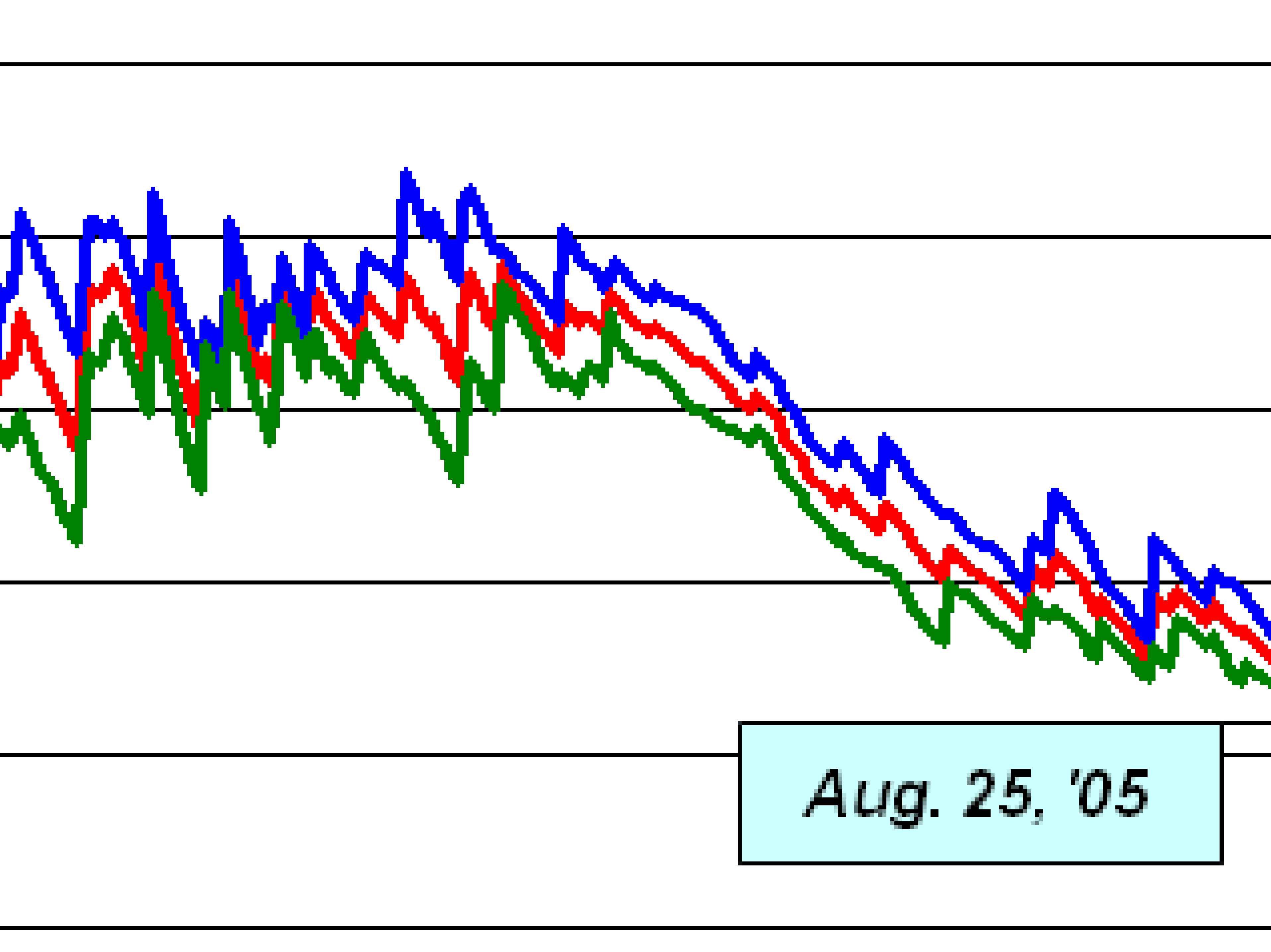


Array Management

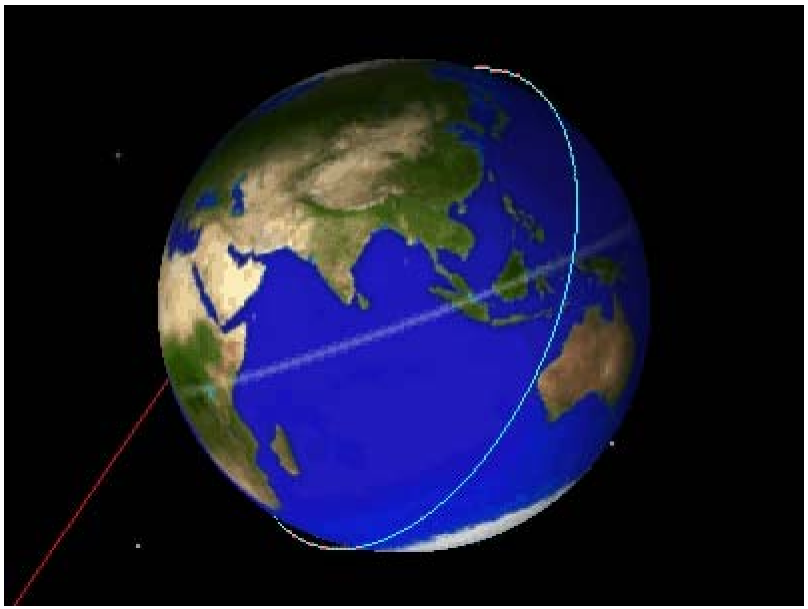
Optimizing several things at once

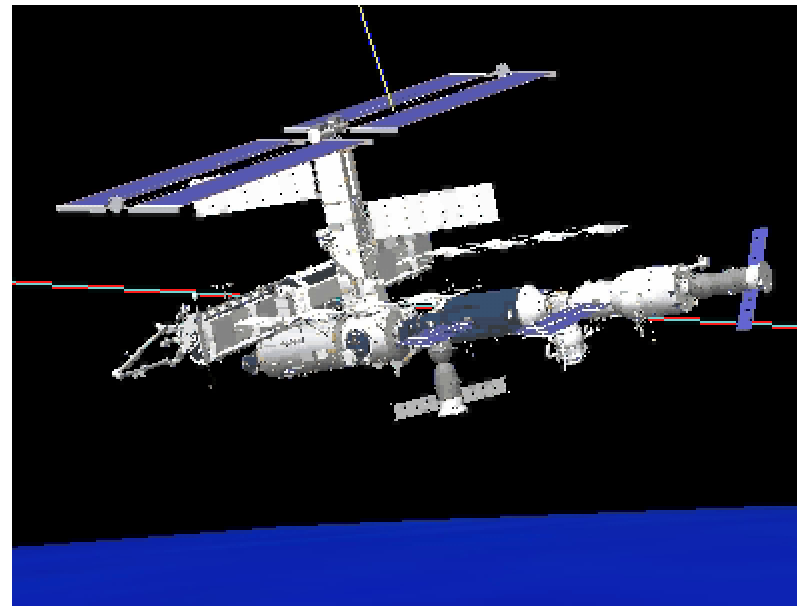
- Drag and Altitude




Aug. 25, '05

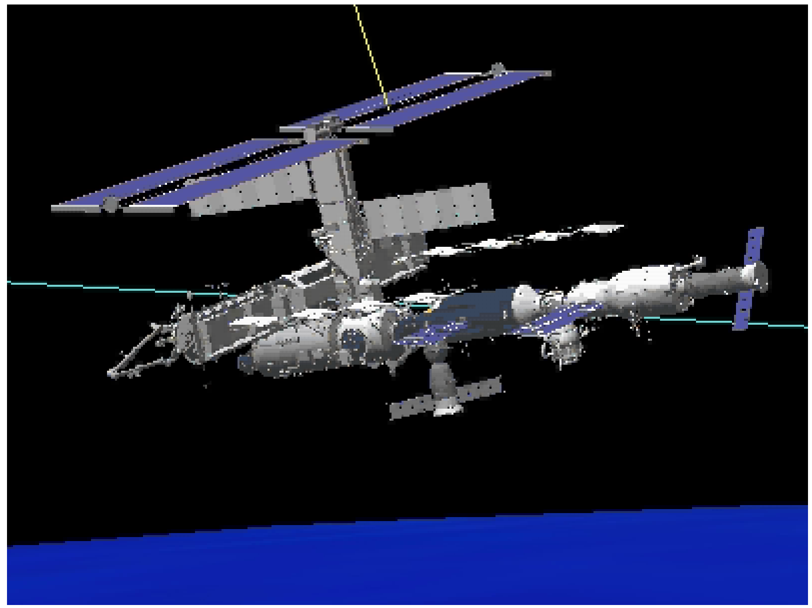
XVV





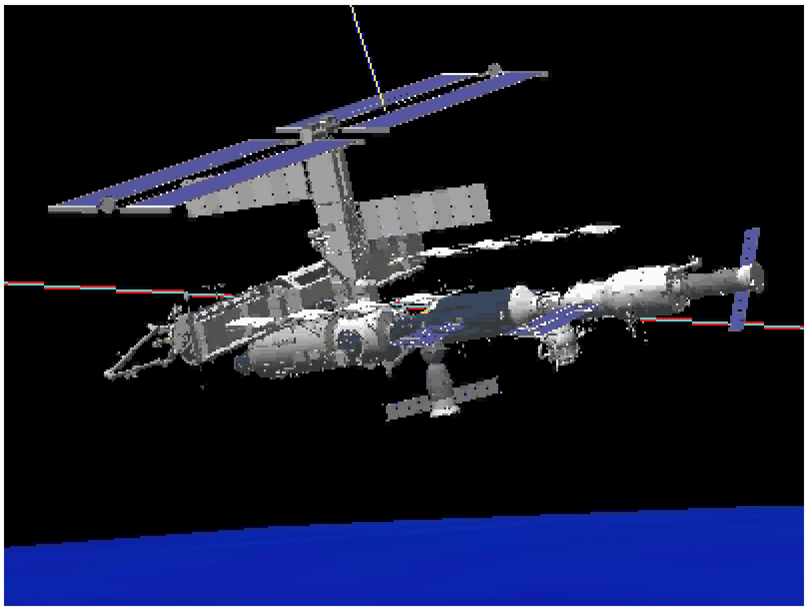
XVV== X axis into the Velocity Vector

XVV DUAL ANGLE

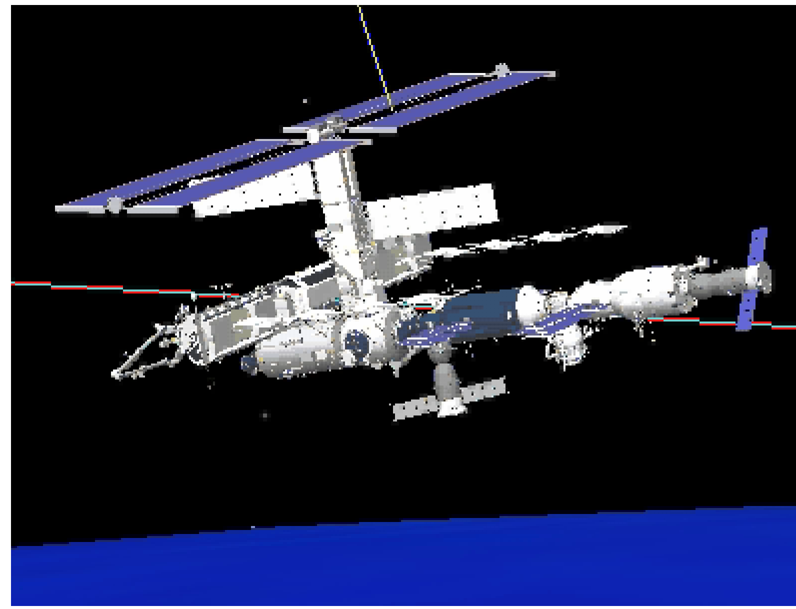


Saves Beta Gimbal Wear and tear: 50% of motion relative to full tracking

XVV “NIGHT GLIDER”



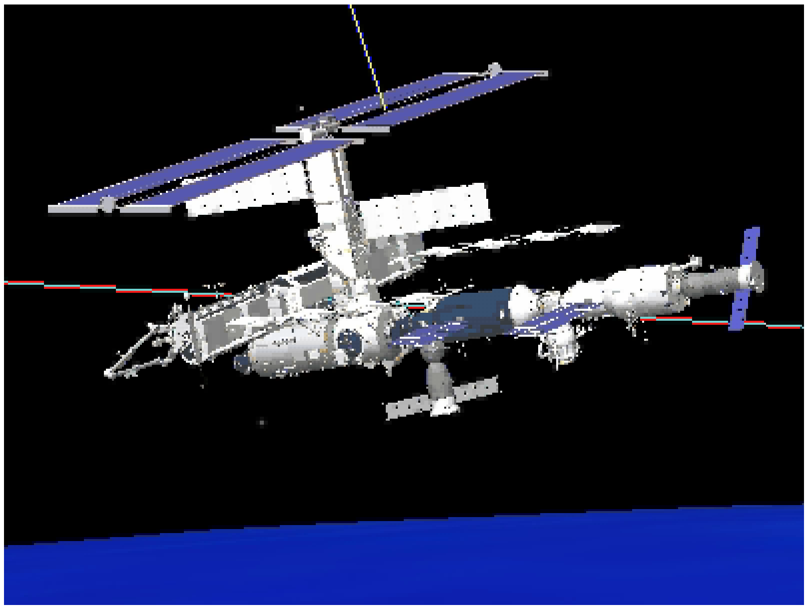
Night Glider (right) vs Dual Angle (left)



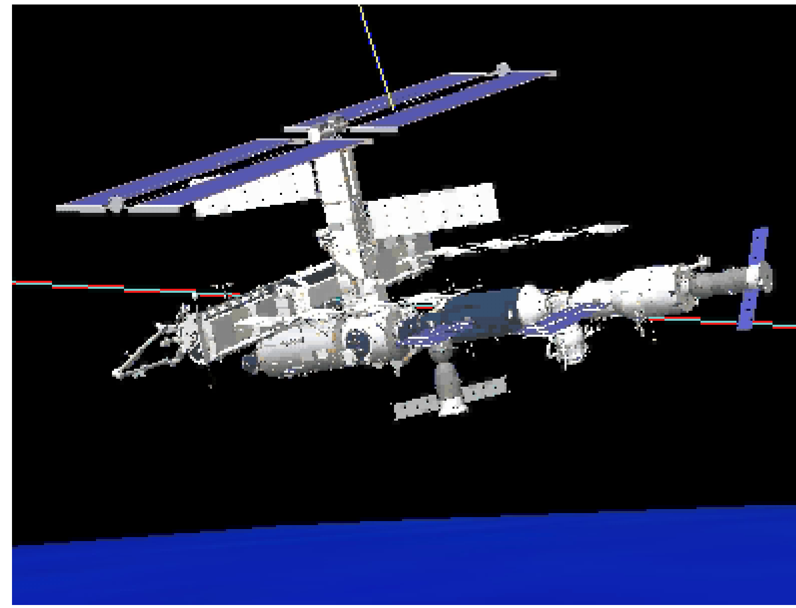
Night Glider (both arrays)

Same rotations as Dual Angle mode, but timed to present minimum drag

XVV “DIET NIGHT GLIDER”



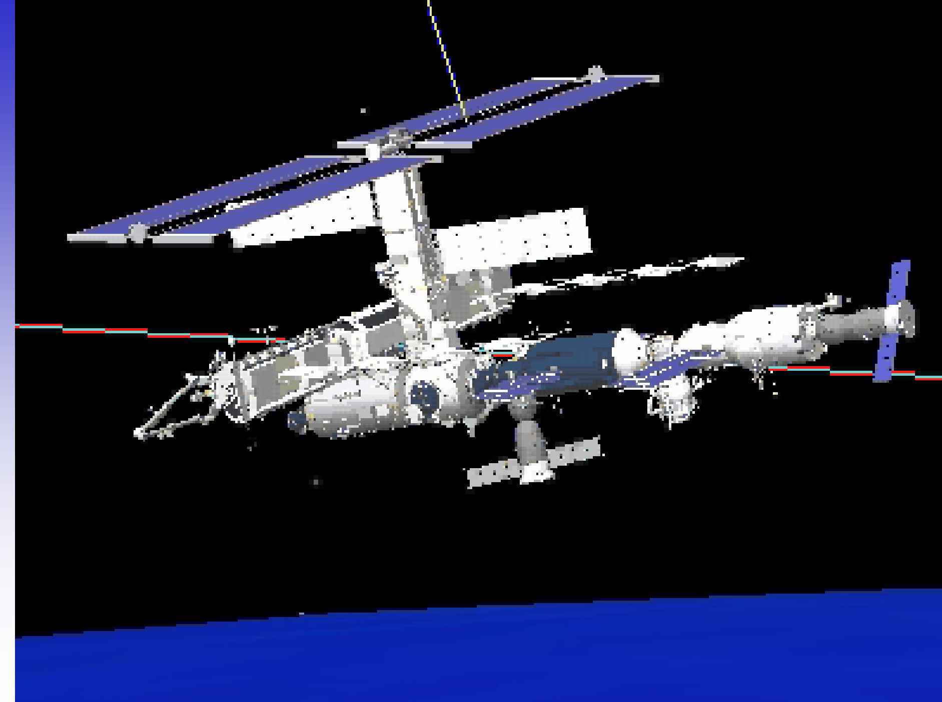
Diet Night Glider (right) vs Night Glider (left)

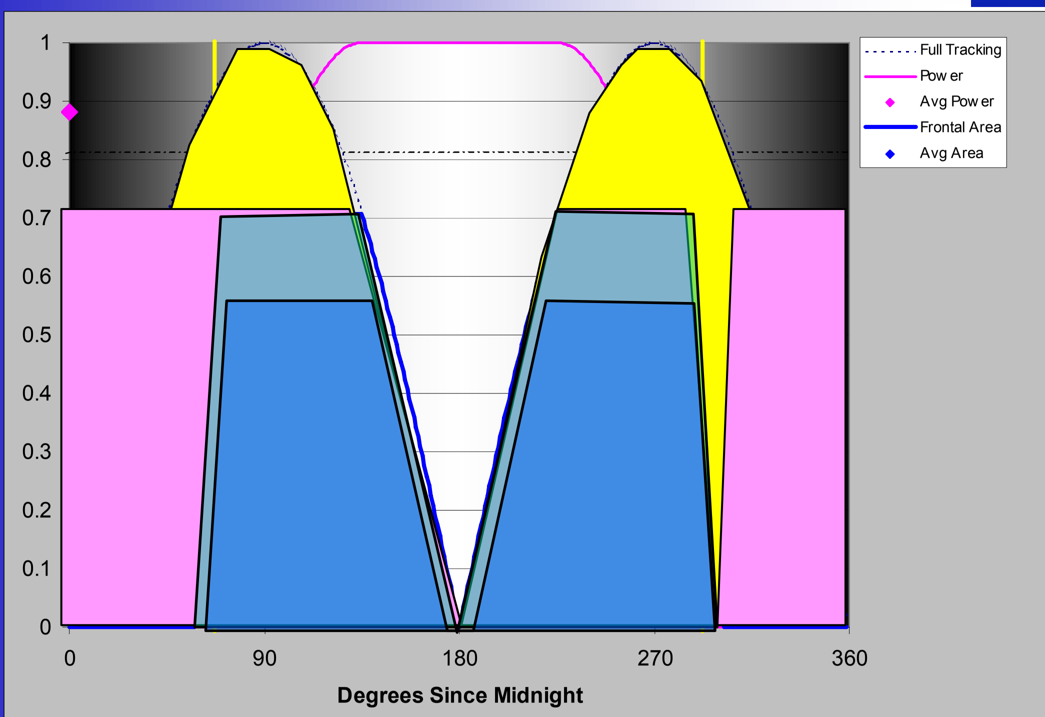


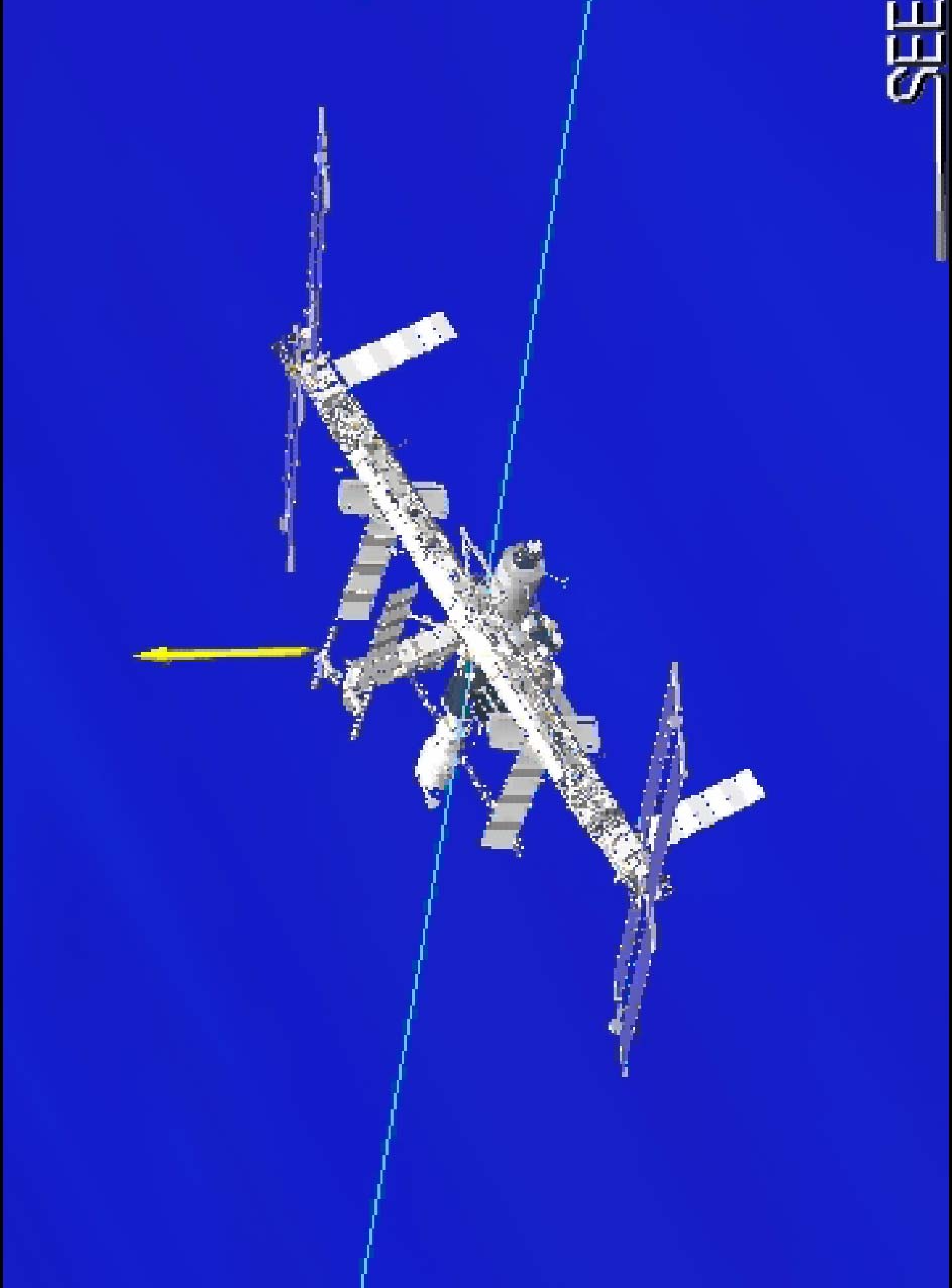
Diet Night Glider

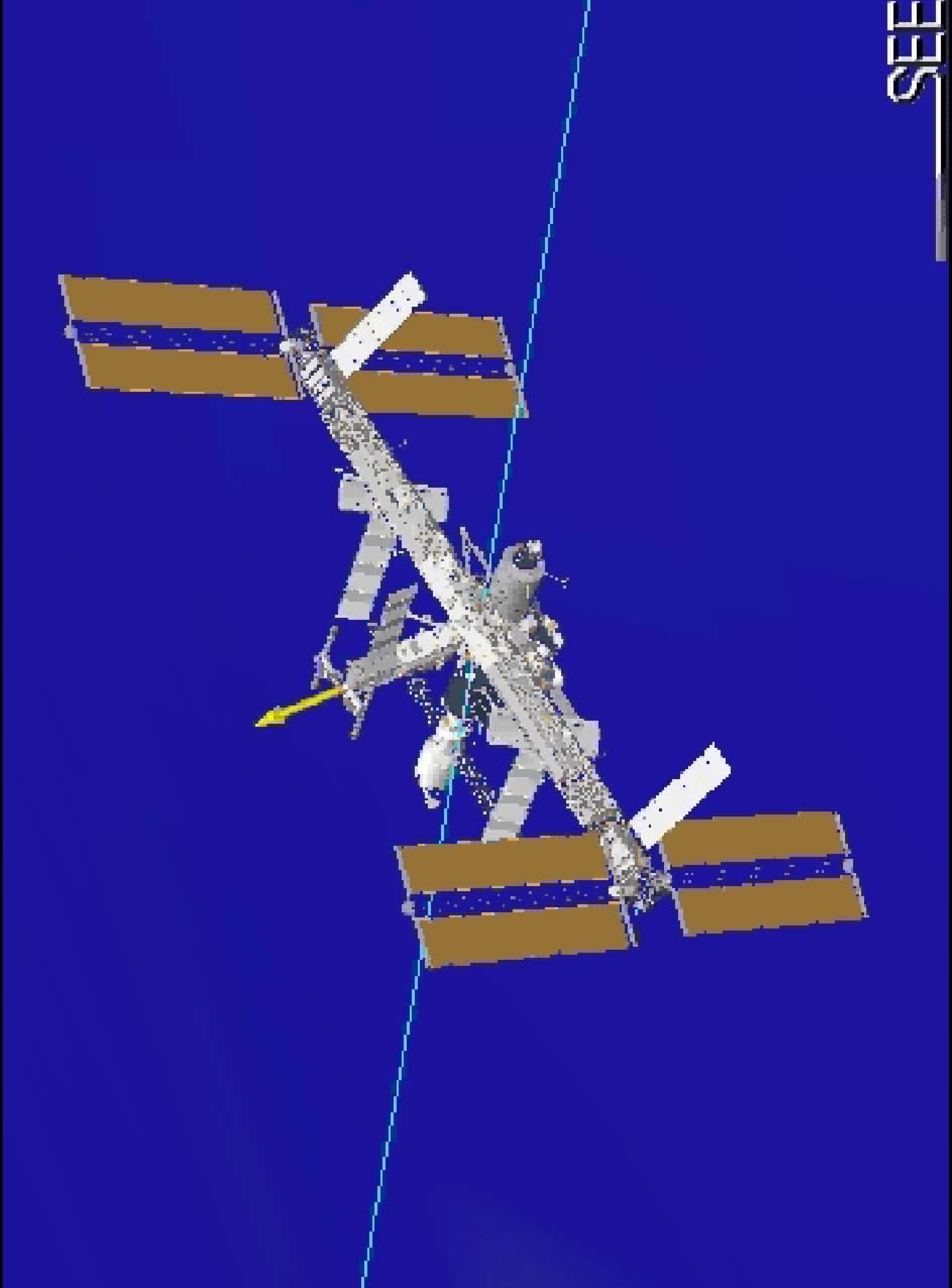
Same rotations as Night Glider mode, but even further reduction of Beta Gimbal rotation. Reduces BGA wear and reduces drag.

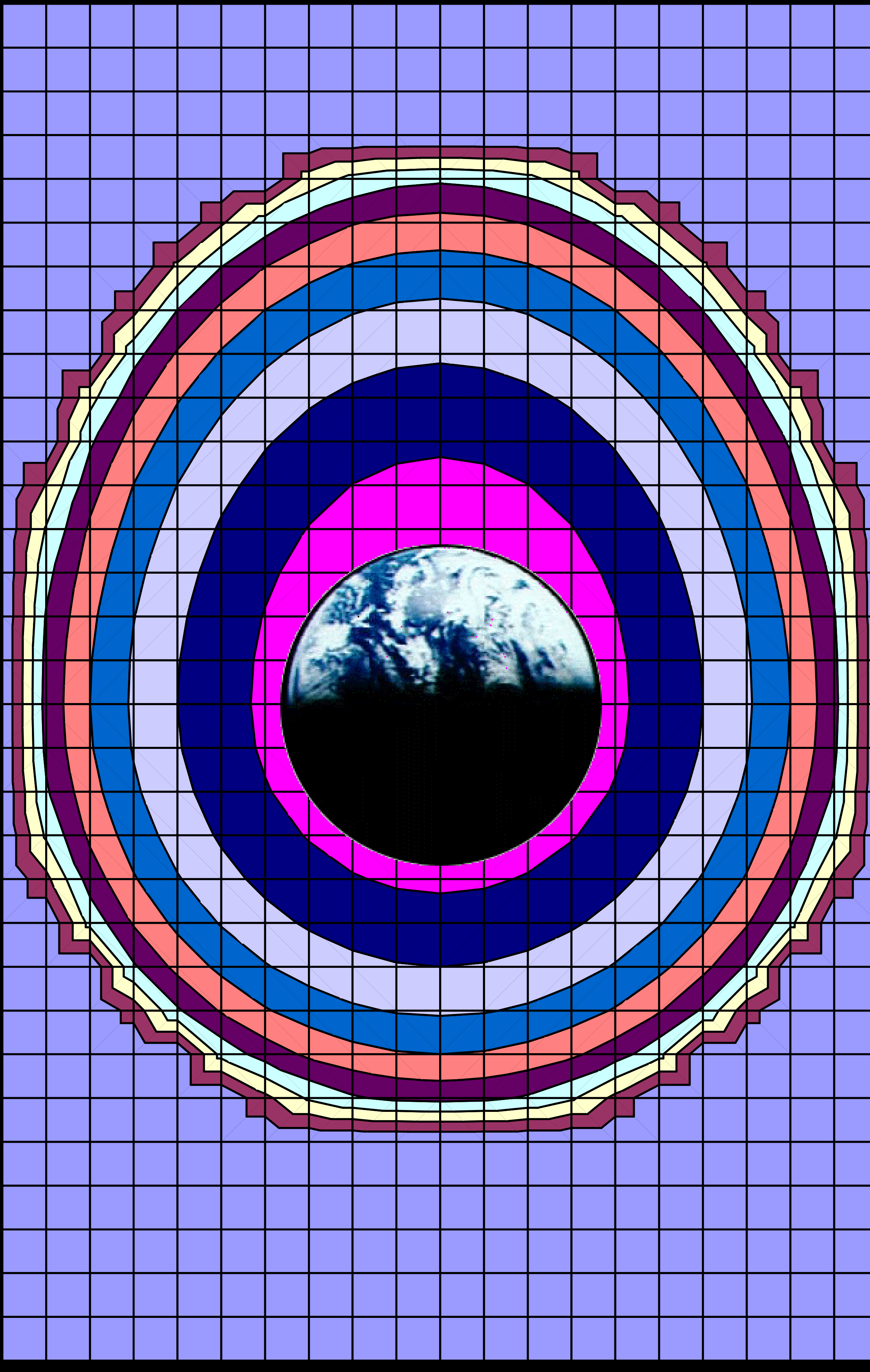
- Drag and Area: Full Sweep, Dual Angle, Night Glider and Diet Night Glider

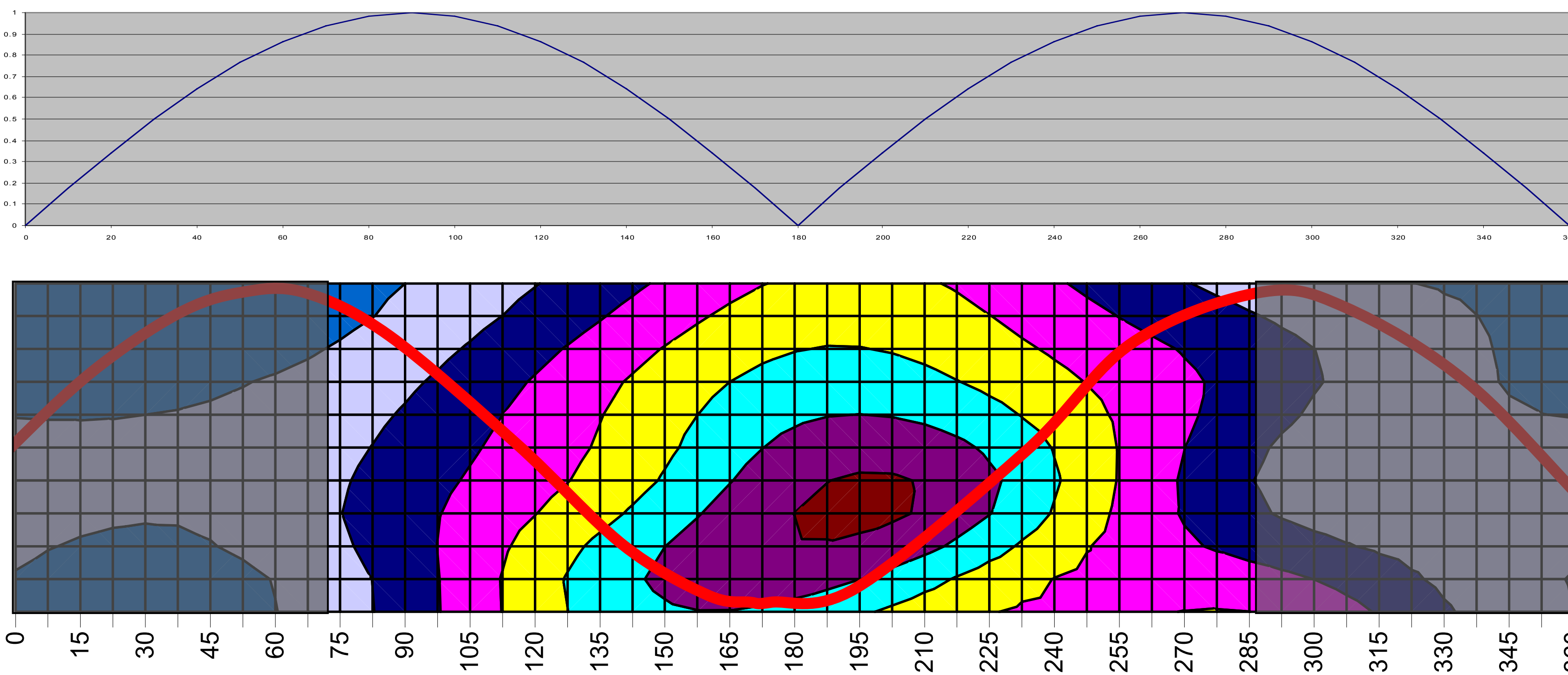






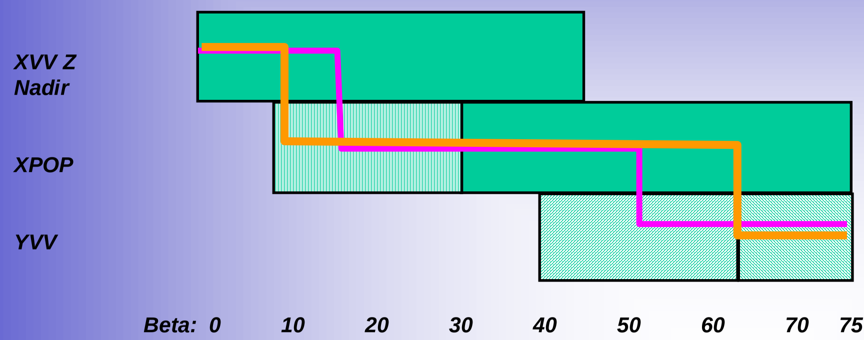


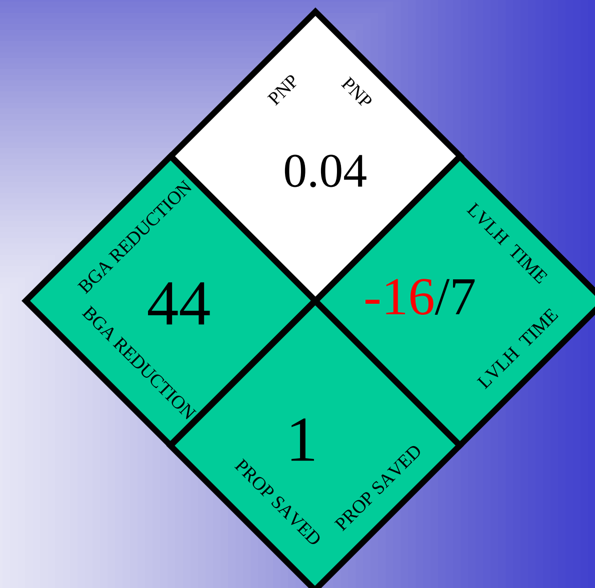




0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360

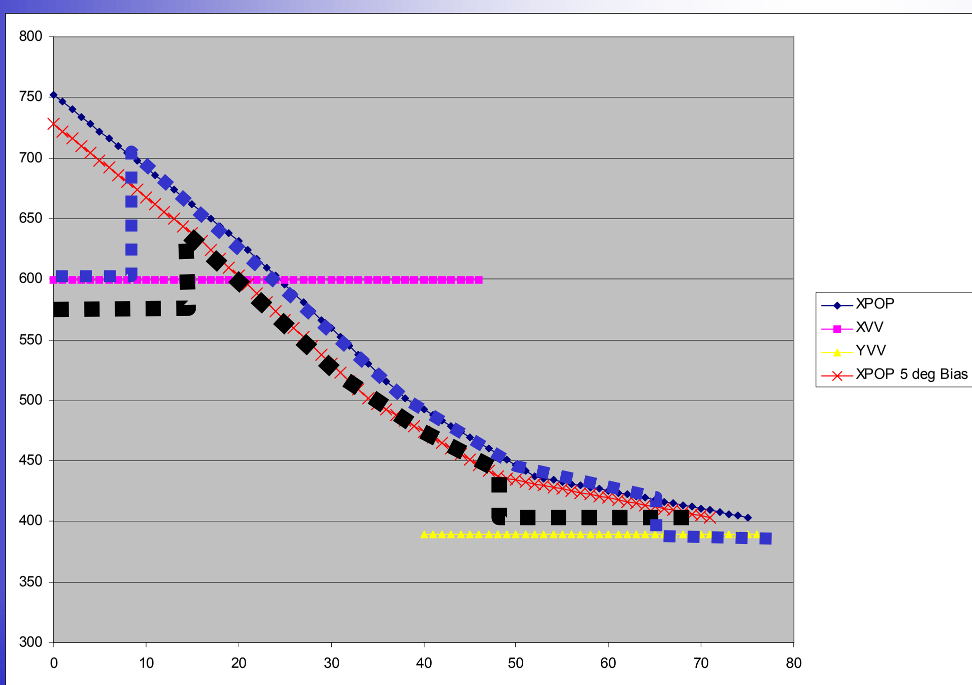
- Integrated performance trades

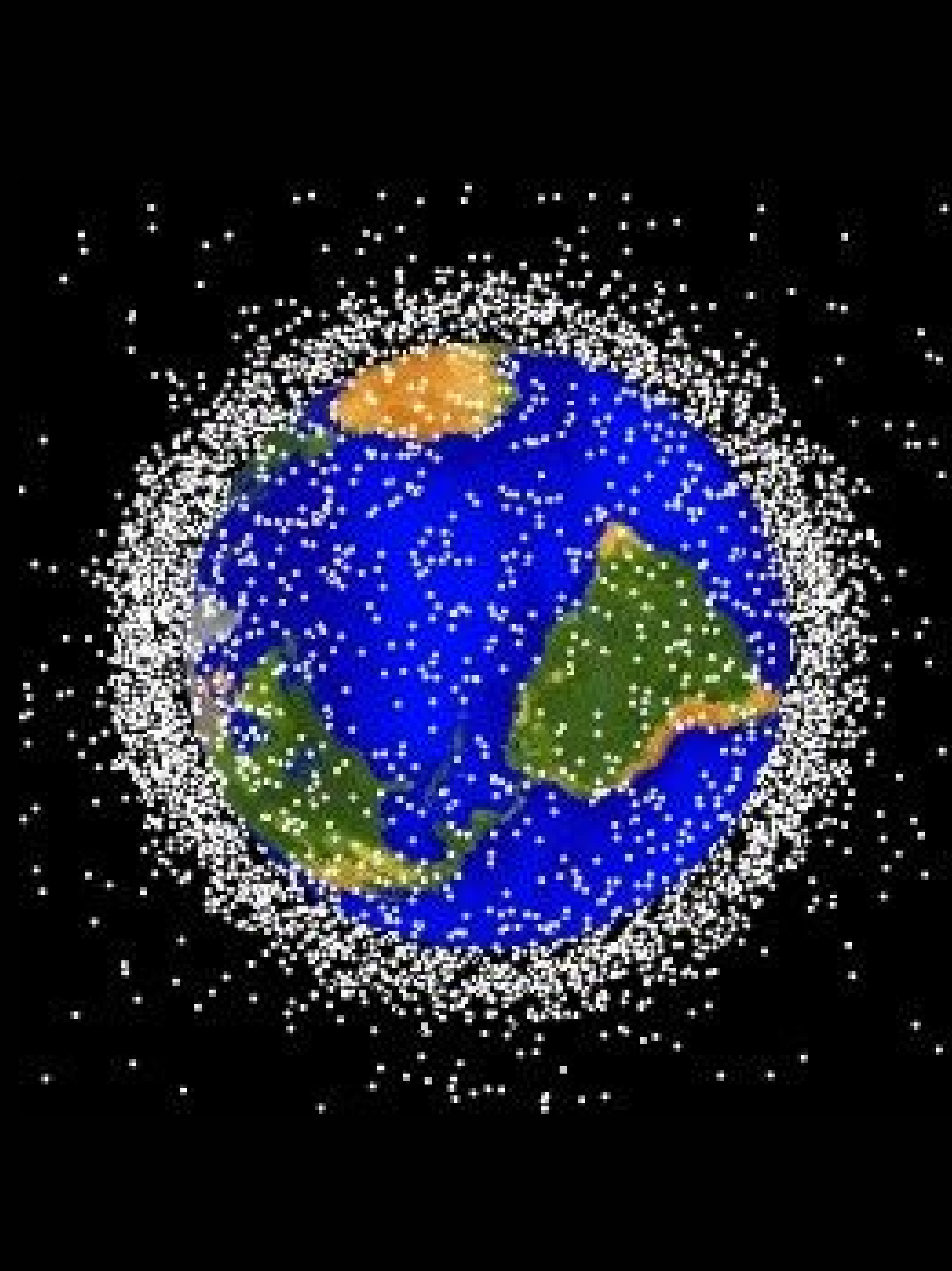


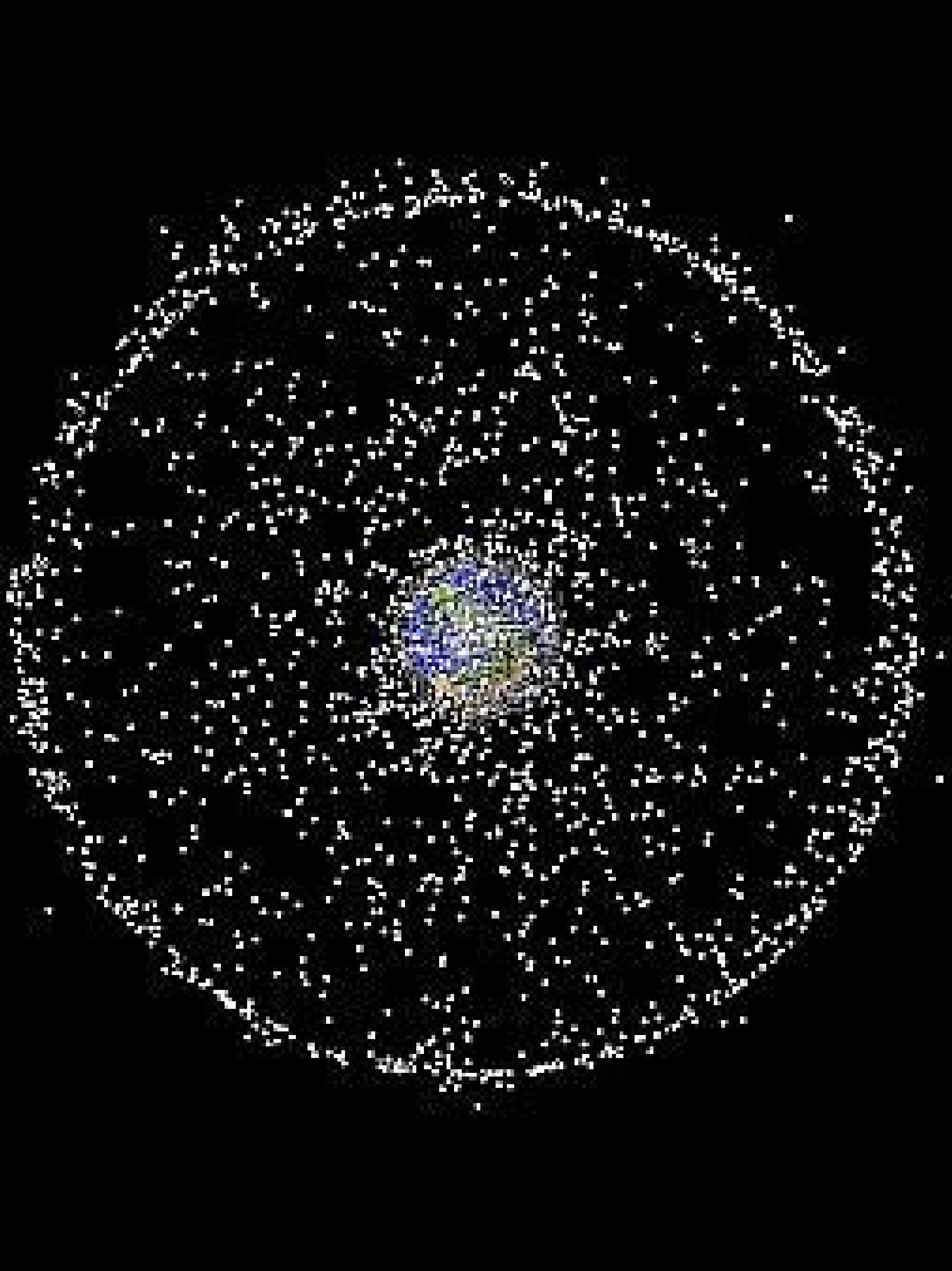


BGA	Bias	XVV max	XPOP max
60	47	11	55

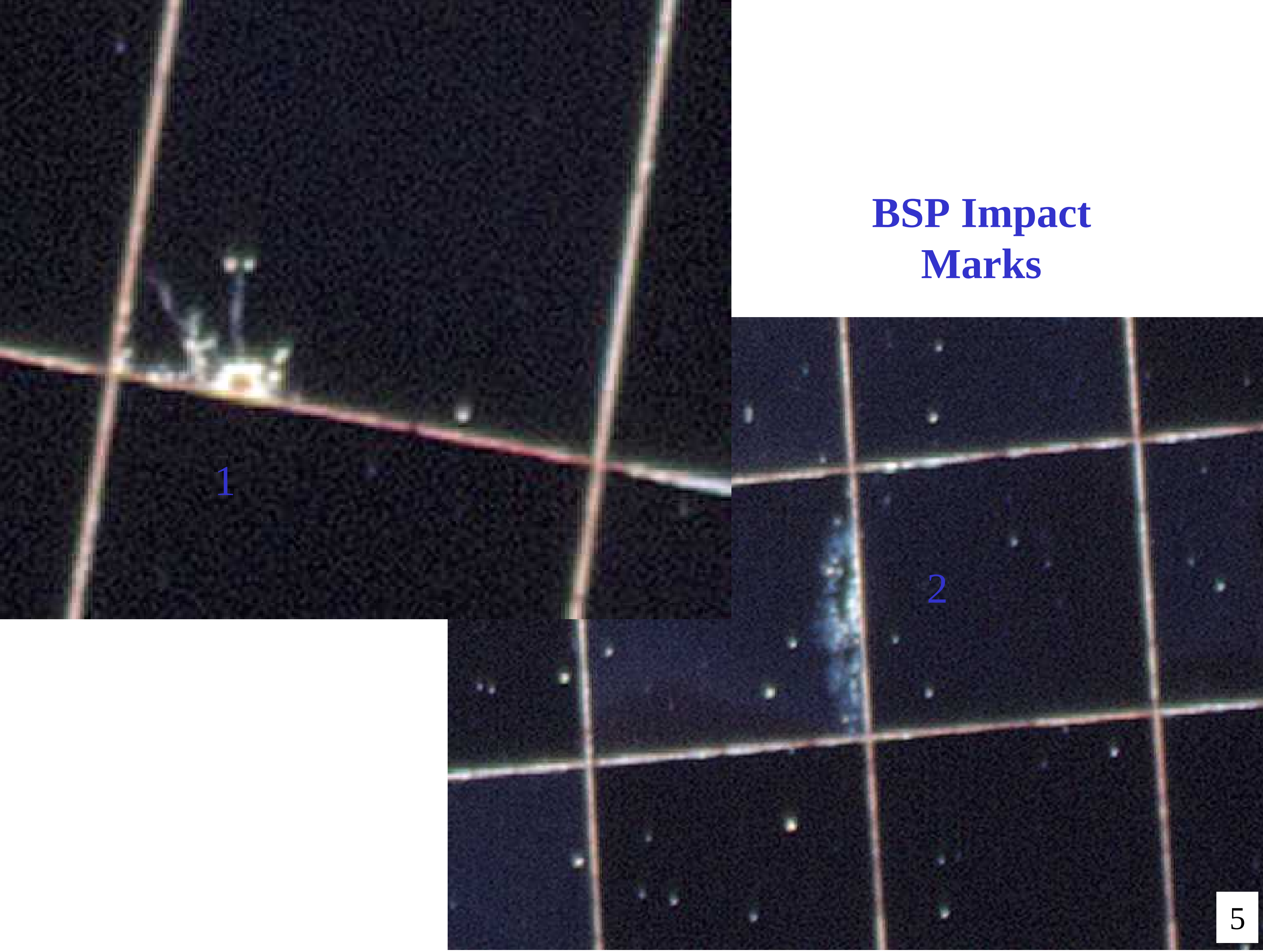
XVV power	XPOP power
10.8	11.4



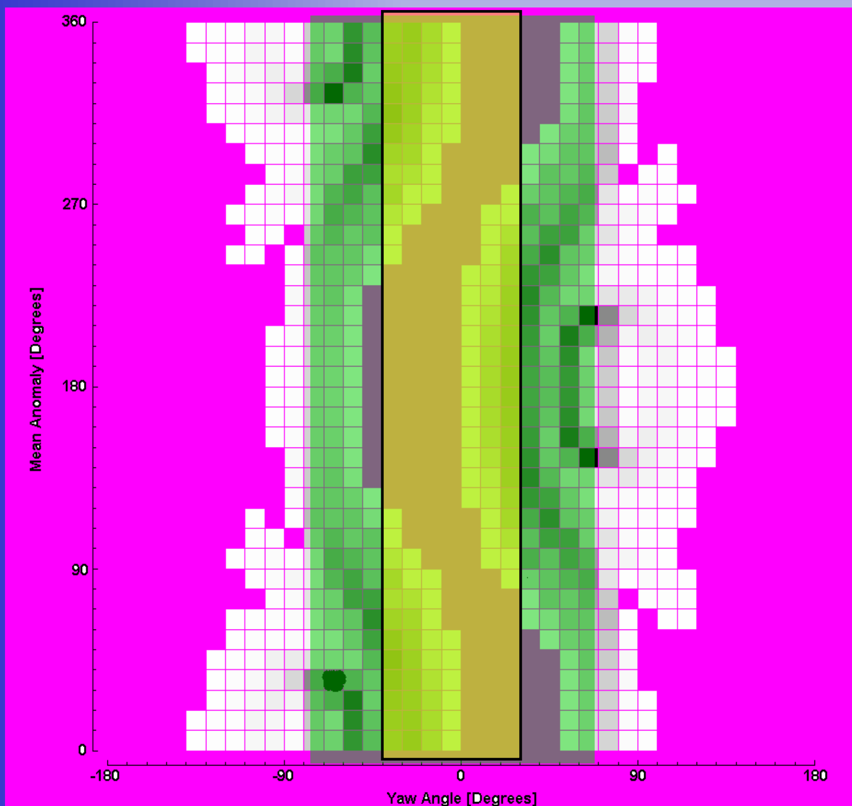




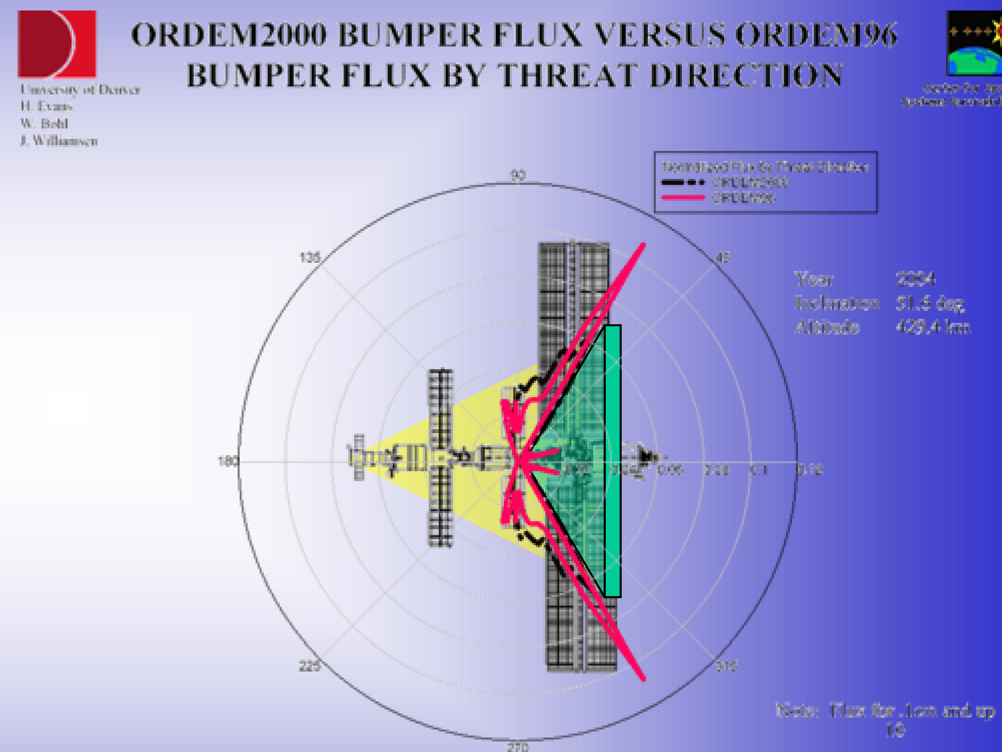
BSP Impact Marks

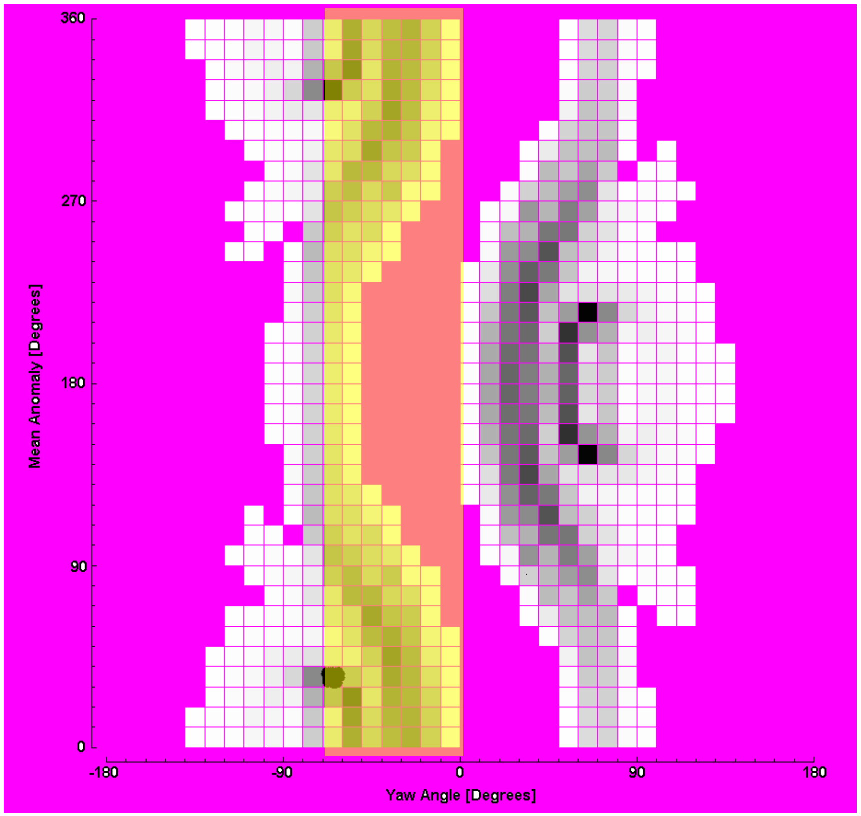


- MMOD Direction



Data supplied by Mark Matney/SX

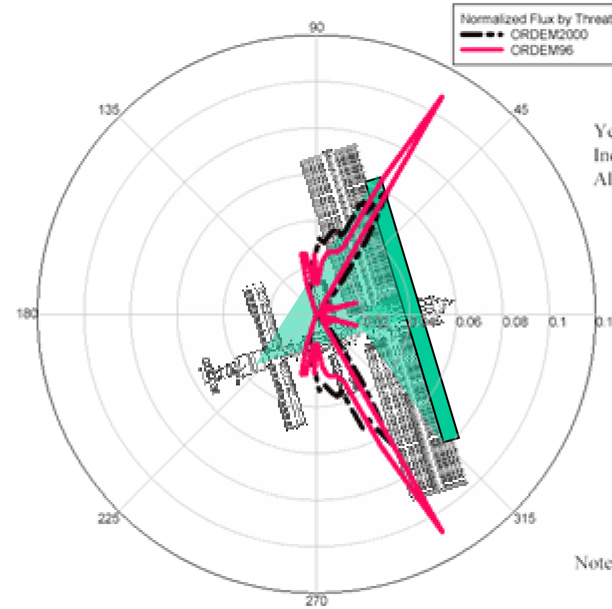




ORDEM2000 BUMPER FLUX VERSUS ORDEM96 BUMPER FLUX BY THREAT DIRECTION

University of Denver
H. Evans
W. Bohl
J. Williamsen

Center for Space Systems Survivability

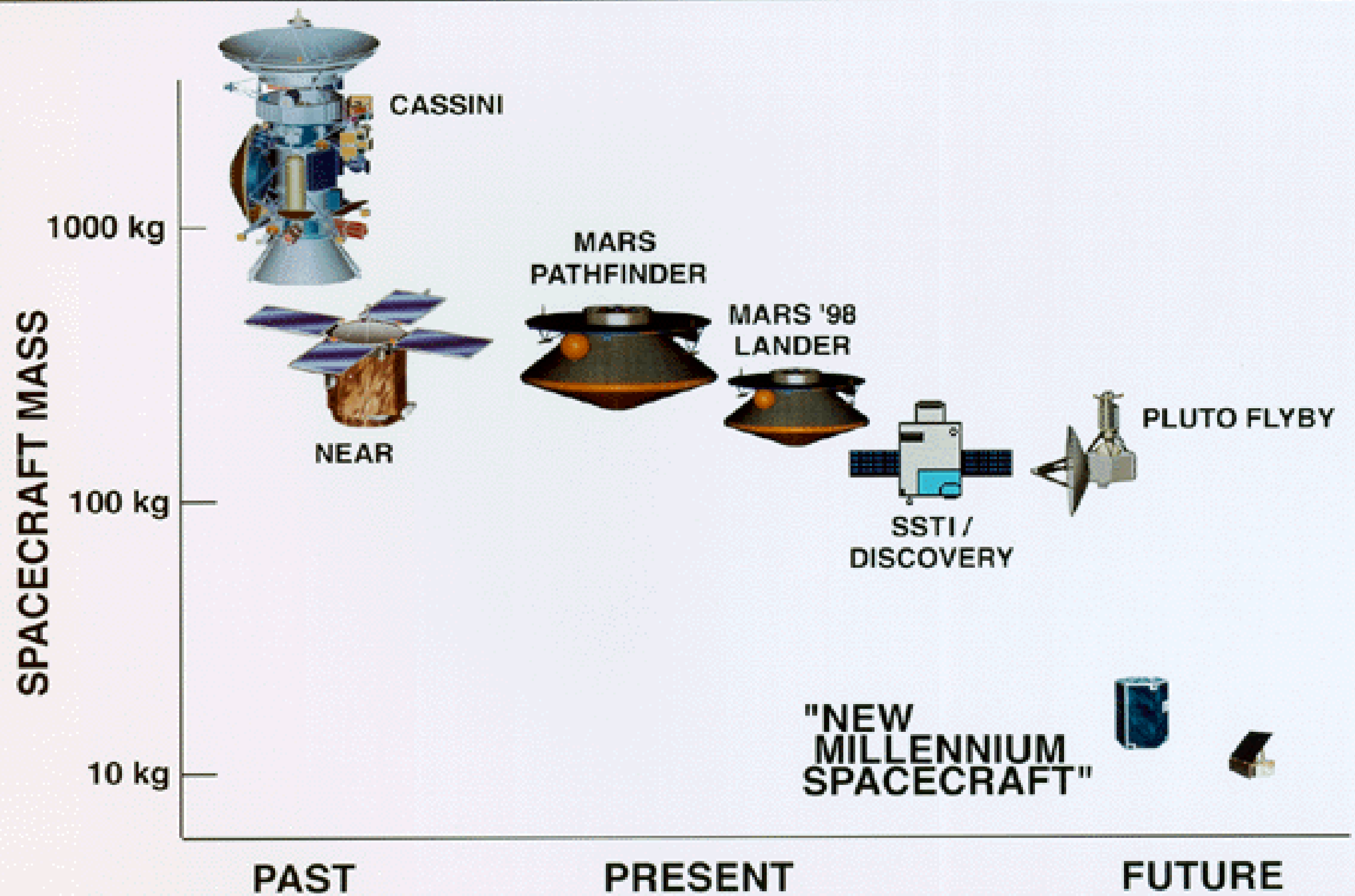


Year 2004
Inclination 51.6 deg
Altitude 429.4 km

Note: Flux for .1cm and up
10

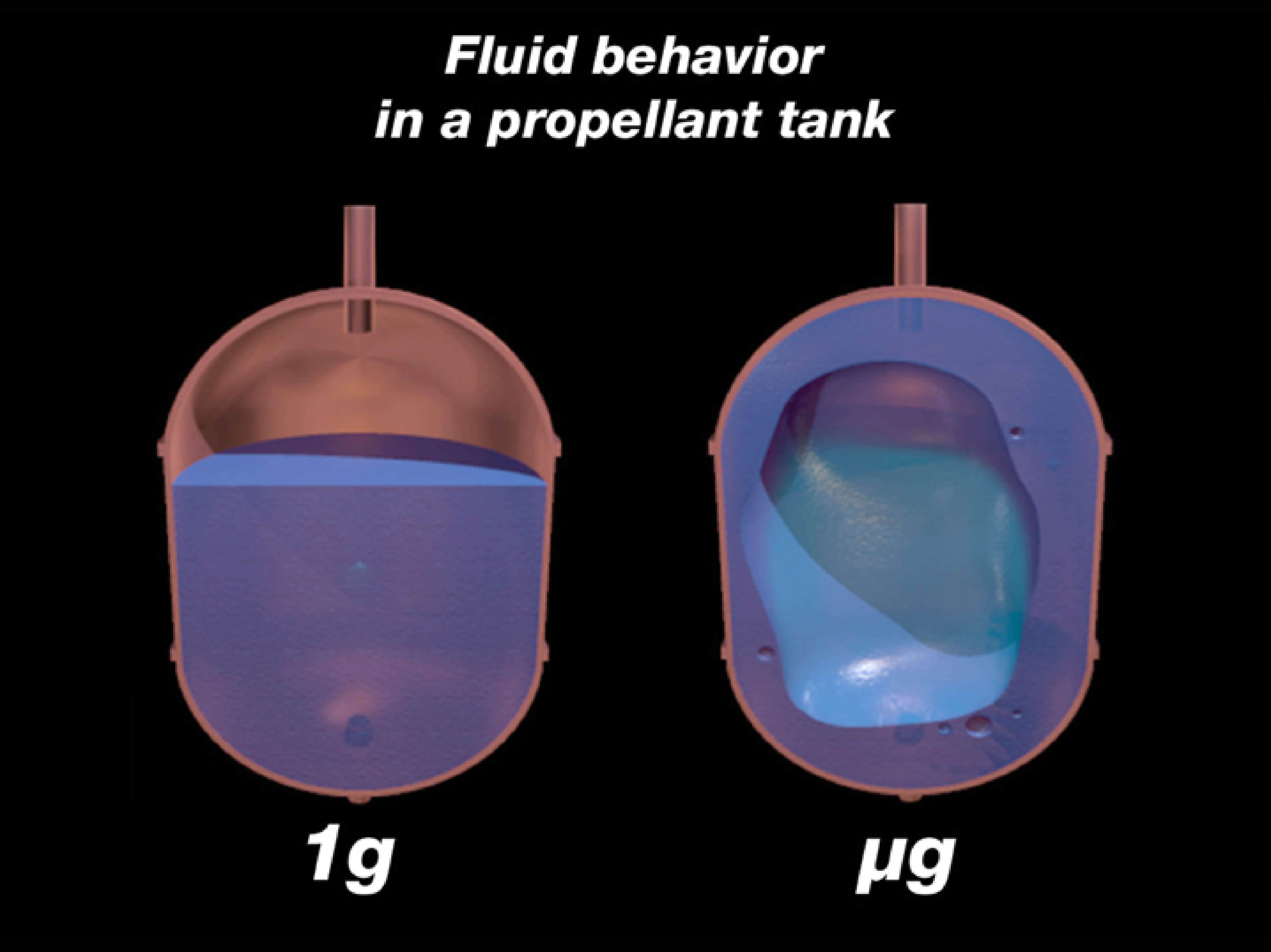
Building There:
(We're not in Kansas anymore Toto…)

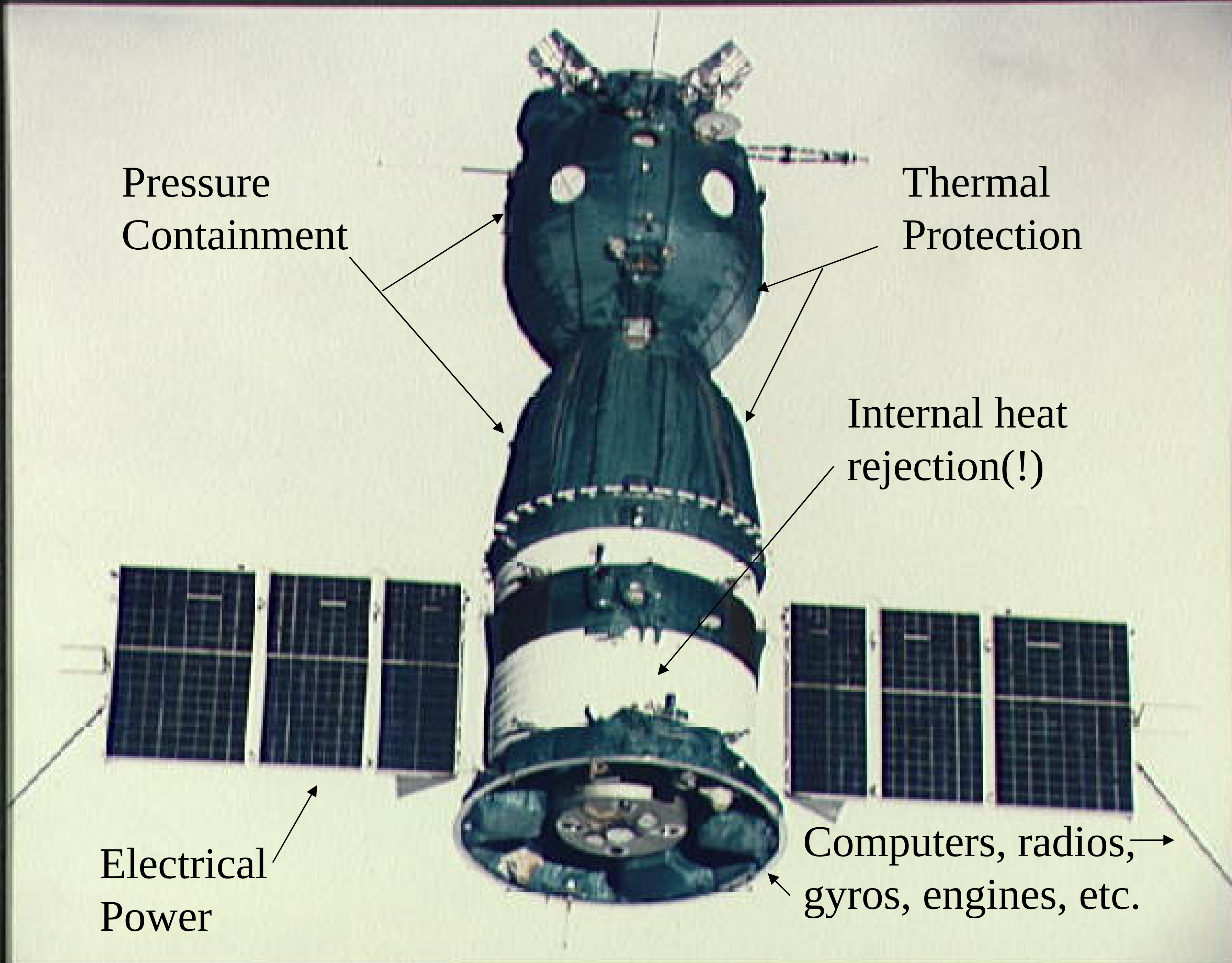
REVOLUTIONIZING SPACECRAFT MASS: TOWARD A "SPACECRAFT ON A CHIP"



Which bug has more software?


Dave Brown
Rick Husband
Laurel Clark
Willie McCool
Ilan Ramon
BROWN CLARK CHAWLA ANDERSON RAMON
HUSBAND MCCOOL
STS 107


Fluid behavior
in a propellant tank
1g
μg


Pressure Containment
Thermal Protection
Internal heat rejection(!)
Electrical Power
Computers, radios, gyros, engines, etc.

ISS PROGRAM RISK MANAGEMENT

Definitions & Terms

Risk Management- An organized, systematic decision-making process that efficiently identifies risks, assess or analyzes risks, and effectively reduces or eliminates risks to achieving program goals.

Risk Types

Risk- A future event with a negative consequence that has some **probability** of occurring. A risk poses a threat to the crew or vehicle safety, program cost, schedule, or major mission objective. An item whose resolution is unlikely without focused management attention.

Watch Item- An immature risk whose complete scope, impact, and consequence is undefined. A watch item is a risk where existing conditions are not favourable for taking action and the potential for significant impact exists, but the probability is low. Watch items do not require mitigation plans.

Cost Issue- A new requirement to the baseline that requires funding. An existing budgeted item that requires additional funding due to cost, schedule, or technical impacts. Cost issues have predominantly cost consequences and can be used to track liens against program reserves.

Concern- A concern is a candidate risk. It does not have enough information available to assess and define mitigation plans. When a candidate risk is identified it is initially entered in the ISS database system as a concern. The candidate risk remains a concern while the risk is being analyzed and reviewed by management for escalation.

Escalation Levels

Top Program Risk- Risks that significantly affect the cost, schedule, mission success or safety of flight and require substantial Program resources.

Top Organizational Risk- Primary risks for the organization and deemed to have the greatest significance to the organization.

ISS RM Key Process Steps

- Risks initially entered as a concern
- Managing organizations assign risk owners & elevation level, and monitor mitigation plans
- Risk Owners document risks and mitigation steps in risk database, update risks, and status management.
- Managing organizations report open risks & recent risk closures at the PRAB.
- The Program Manager accepts risks and identifies/approves TPRs (typically at the PRAB)
- All risk activity is documented in the ISS risk database.

ISS RM Assistance

IRMA (Integrated Risk Management Application) is used to document, track, and report program management risks, watch items, cost issues, and concerns. IRMA permissions are
based on the individuals role and area of responsibility. Information regarding ISS Program Risk Management and IRMA can be found at:
http://iss-www.jsc.nasa.gov/ss/issapt/smaprm/SandMARisk.html

Writing A Risk Statement

GIVEN → **CONDITION** There is a **POSSIBILITY** that, → **CONSEQUENCE** **Will Occur**

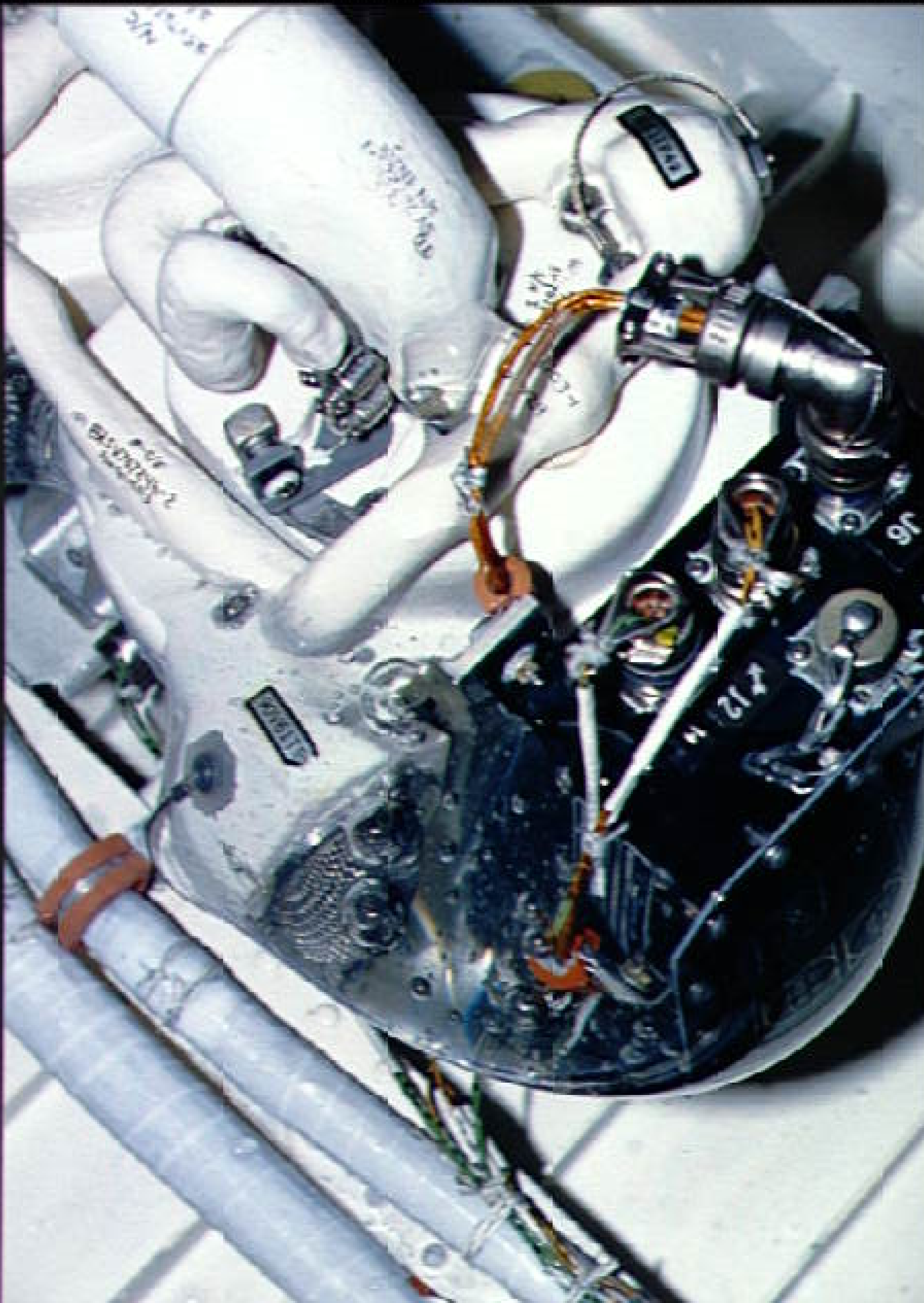
- *Must be a FACT or perceived to be FACT*
- *NO uncertainty attached*
- *Short and concise*

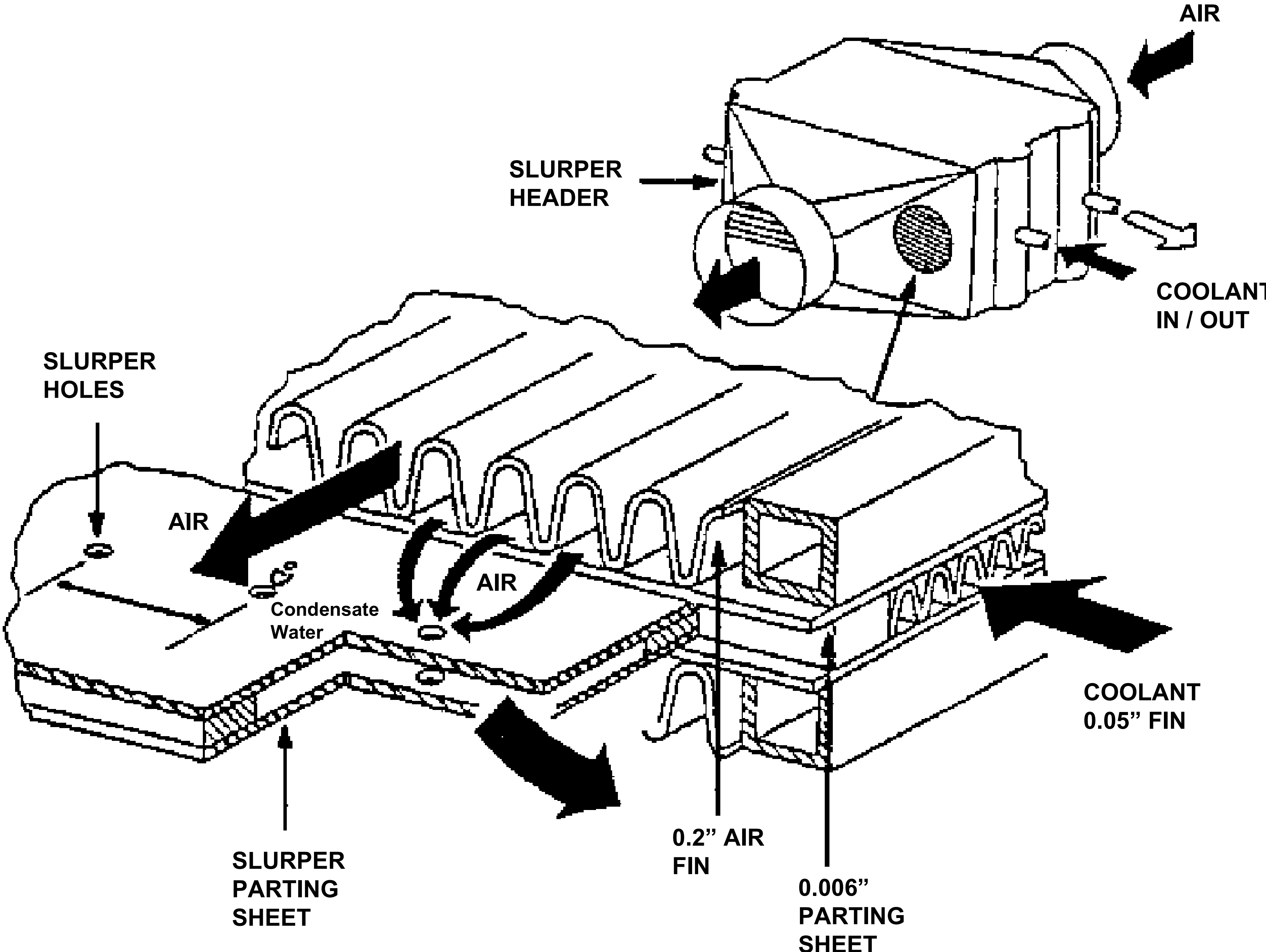
ISS Risk Database Requirements & User Roles

Mandatory Field	Concern	Cost Issue	Watch Item	Risk
1. Title	✓	✓	✓	✓
2. Description/Context			✓	✓
3. Risk Statement	✓	✓	✓	✓
4. ECD			✓	✓
5. Most Likely Mit. Cost (1)				✓
6. High and Lo Mit. Cost (1)				✓
7. Mit. Budget Amount (1)				✓
8. Contract				✓
9. Cost Level				✓
10. Likelihood Score			✓	✓
11. Consequence Score			✓	✓
12. Impact/Consequence				✓
13. Closure/Acceptance Criteria			✓	✓
14. Flights Affected	✓	✓	✓	✓
15. Orgs Affected			✓	✓
16. Current Status				✓
17. Mitigation Plan Overview				✓
18. Mitigation Tasks (3)				✓

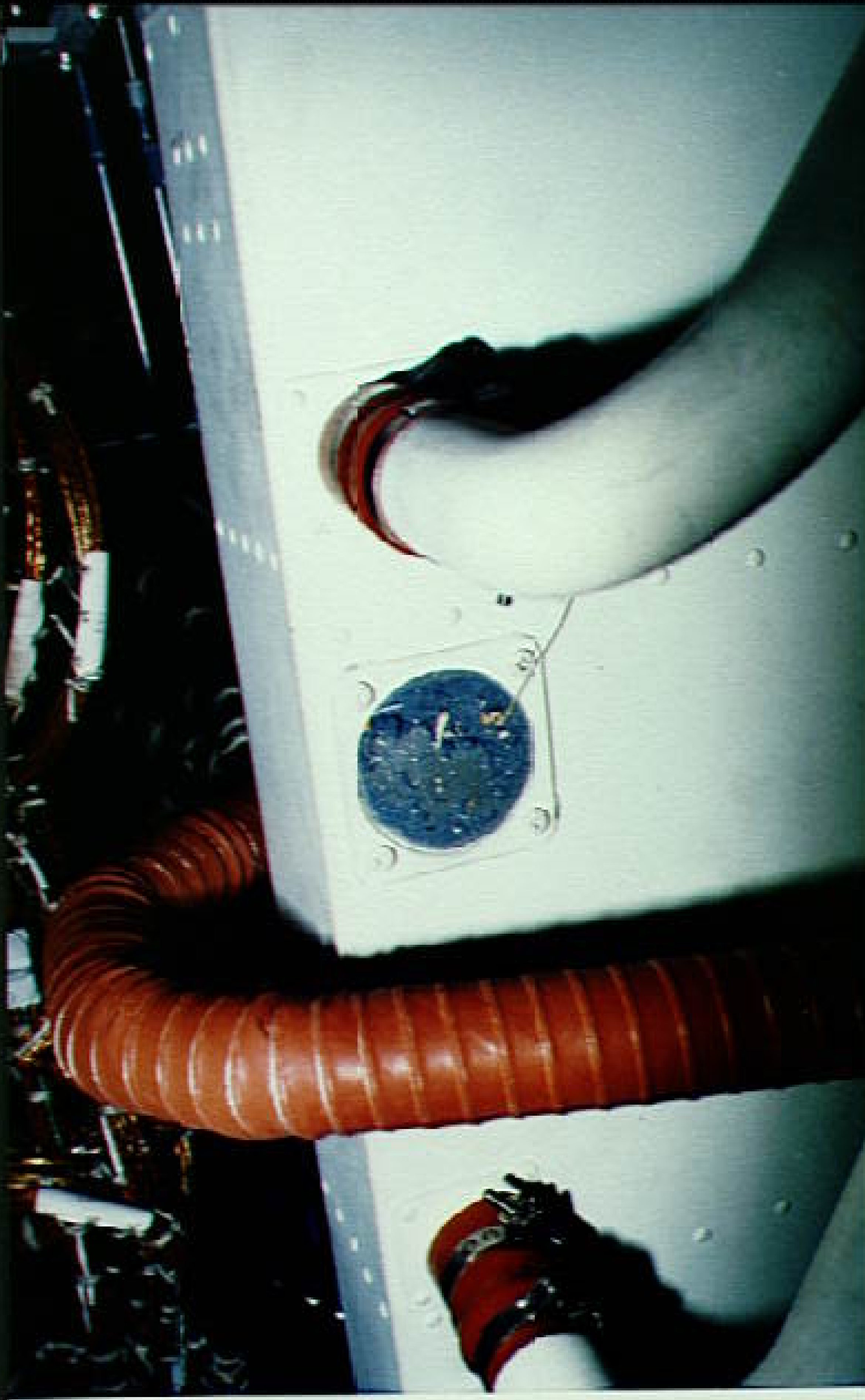
Note: If Cost Threat is selected as "Yes", Cost category and Cost Level are mandatory.
1. At least one Fiscal Year (FY) of cost information
2. At least one consequence score (cost, schedule, technical)
3. At least one mitigation task entered. In addition, for each task entry, need Task Description, MO & ECD.

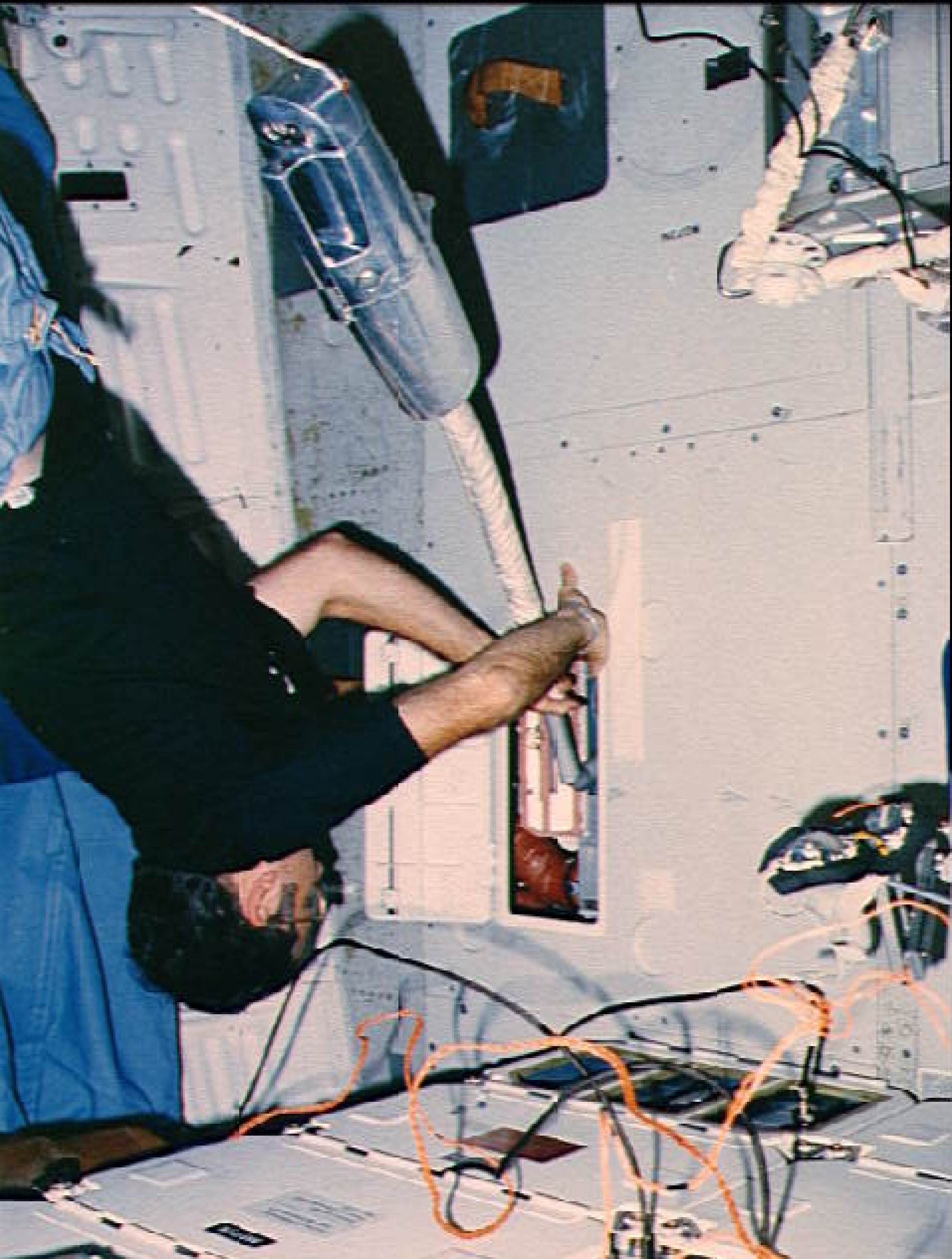
	Capabilities						
Role	Enter & Update an Item	Elevate a Risk	Close Risks, Watch Items, & Cost Issues	Close Concerns	Receive Emails	Unlock Passwords	Assign Yes or No to Cost Threats
Org Users	x			x	items owned by user		
Sub Org POCs	x	x	x	x	items owned by sub-org		
Org POCs	x	x	x	x	items owned by org & items where designated as affected org		
BPOC					items with costs identified		x
Sys Admin	x	x	x	x	All items	x	x





AIR
SLURPER HEADER
COOLANT IN / OUT
SLURPER HOLES
AIR
AIR
Condensate Water
COOLANT 0.05” FIN
SLURPER PARTING SHEET
0.2” AIR FIN
0.006” PARTING SHEET





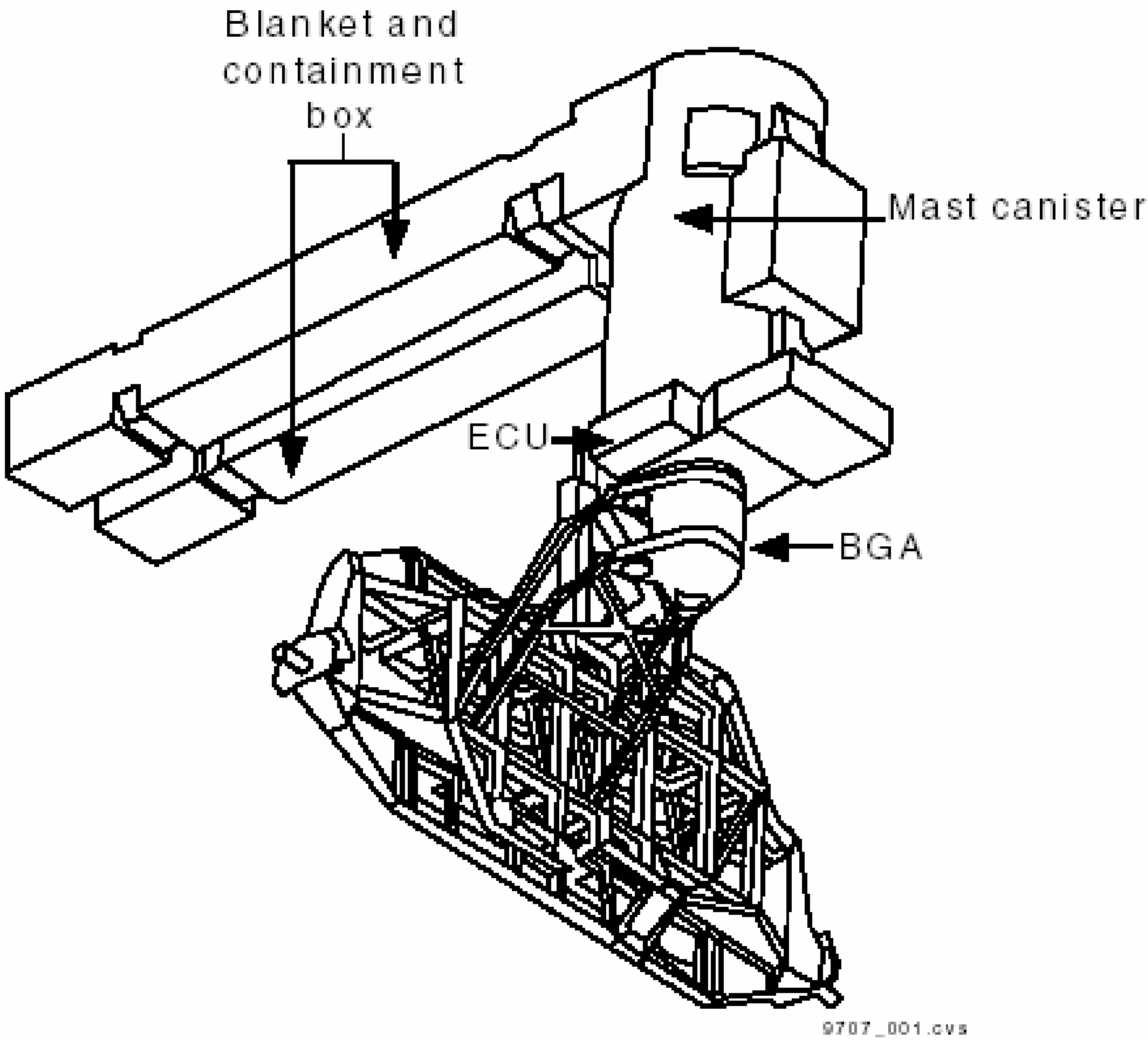


Figure 2.1-2. Energy collection and conversion ORUs, stowed configuration

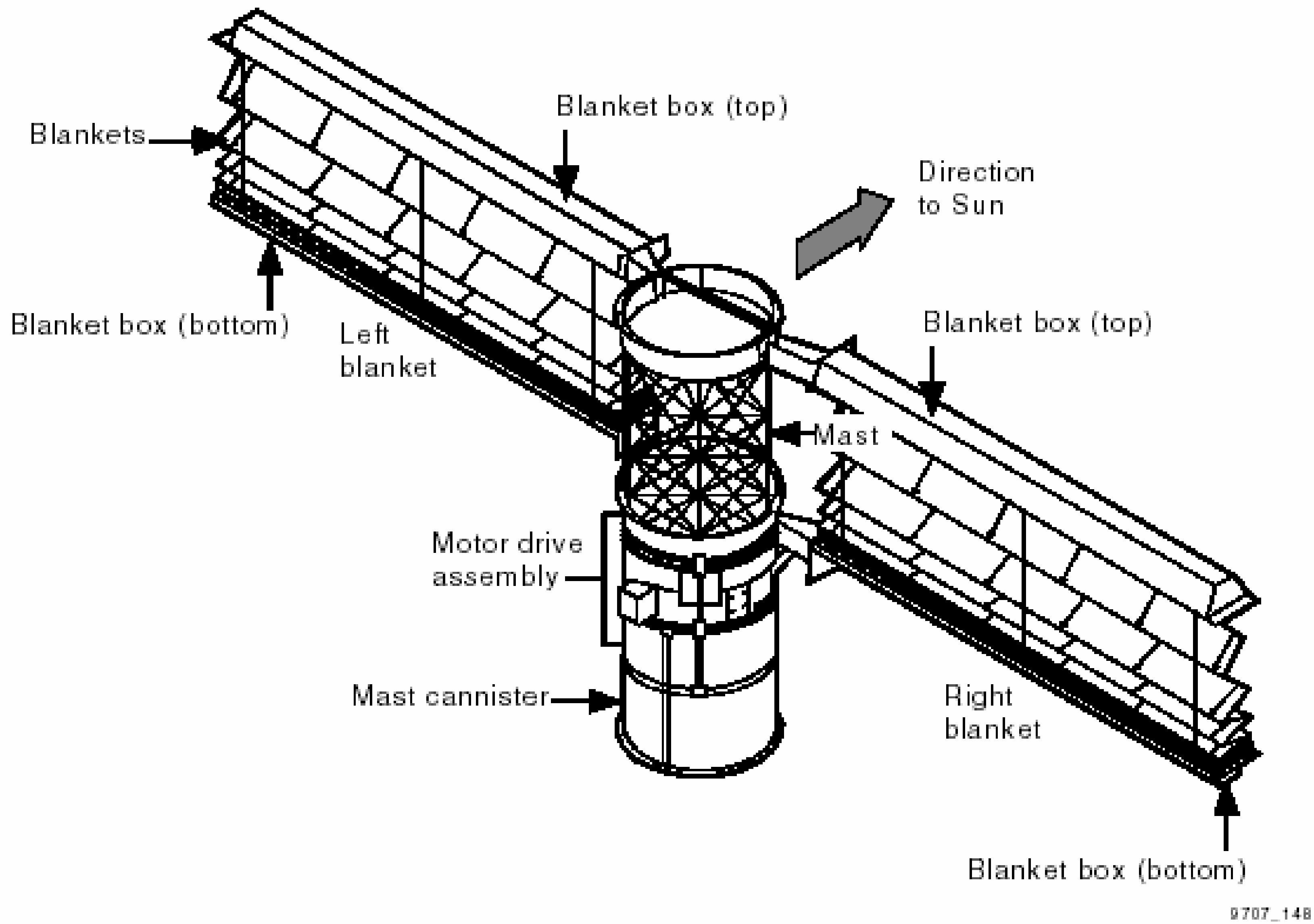


Figure 2.1-1. Partially deployed solar array wing

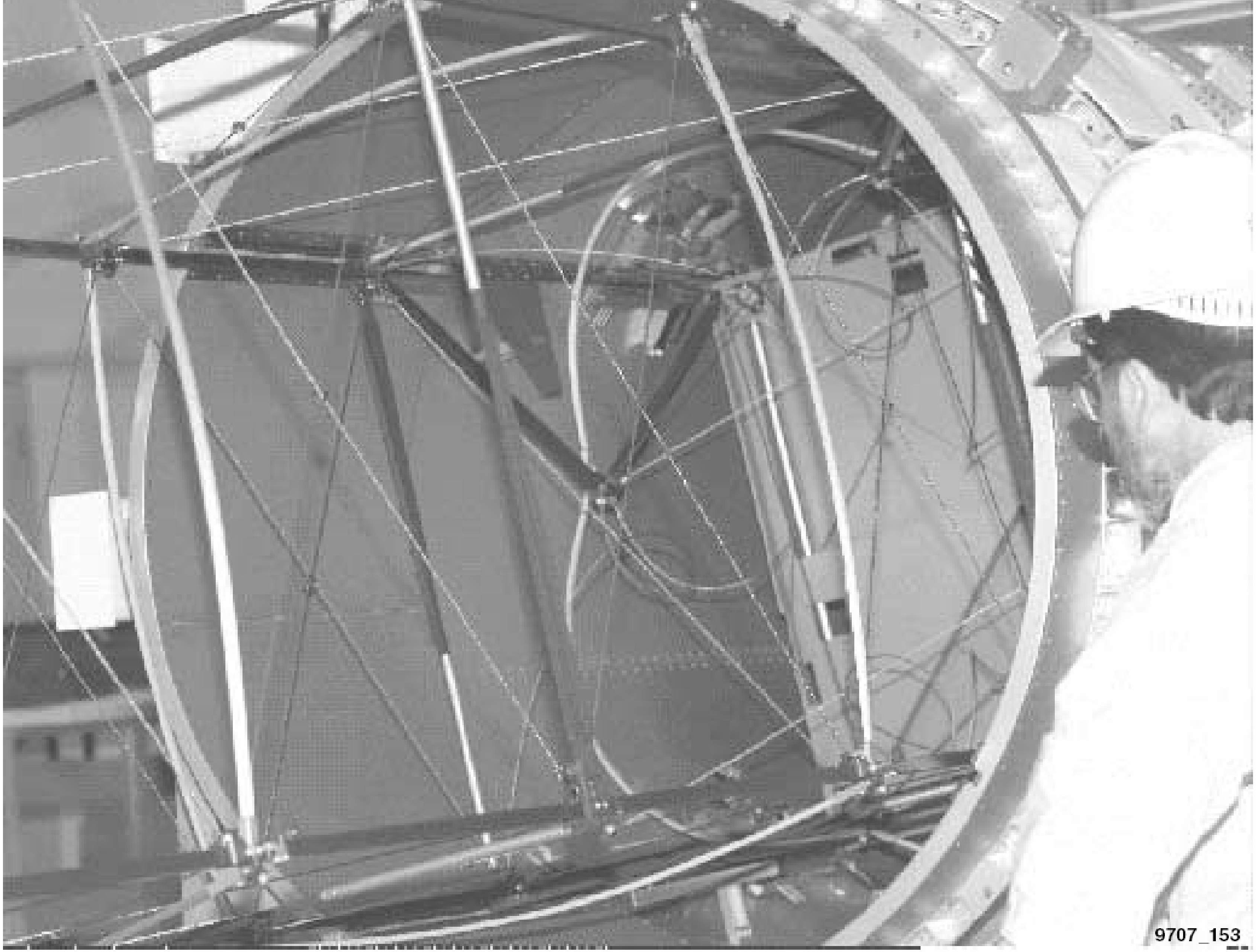


Figure 2.1-9. Mast canister on right, with mast partially deployed to the left

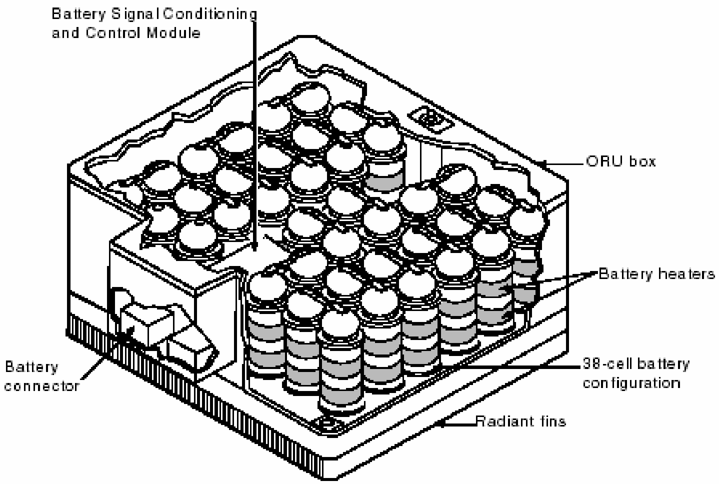
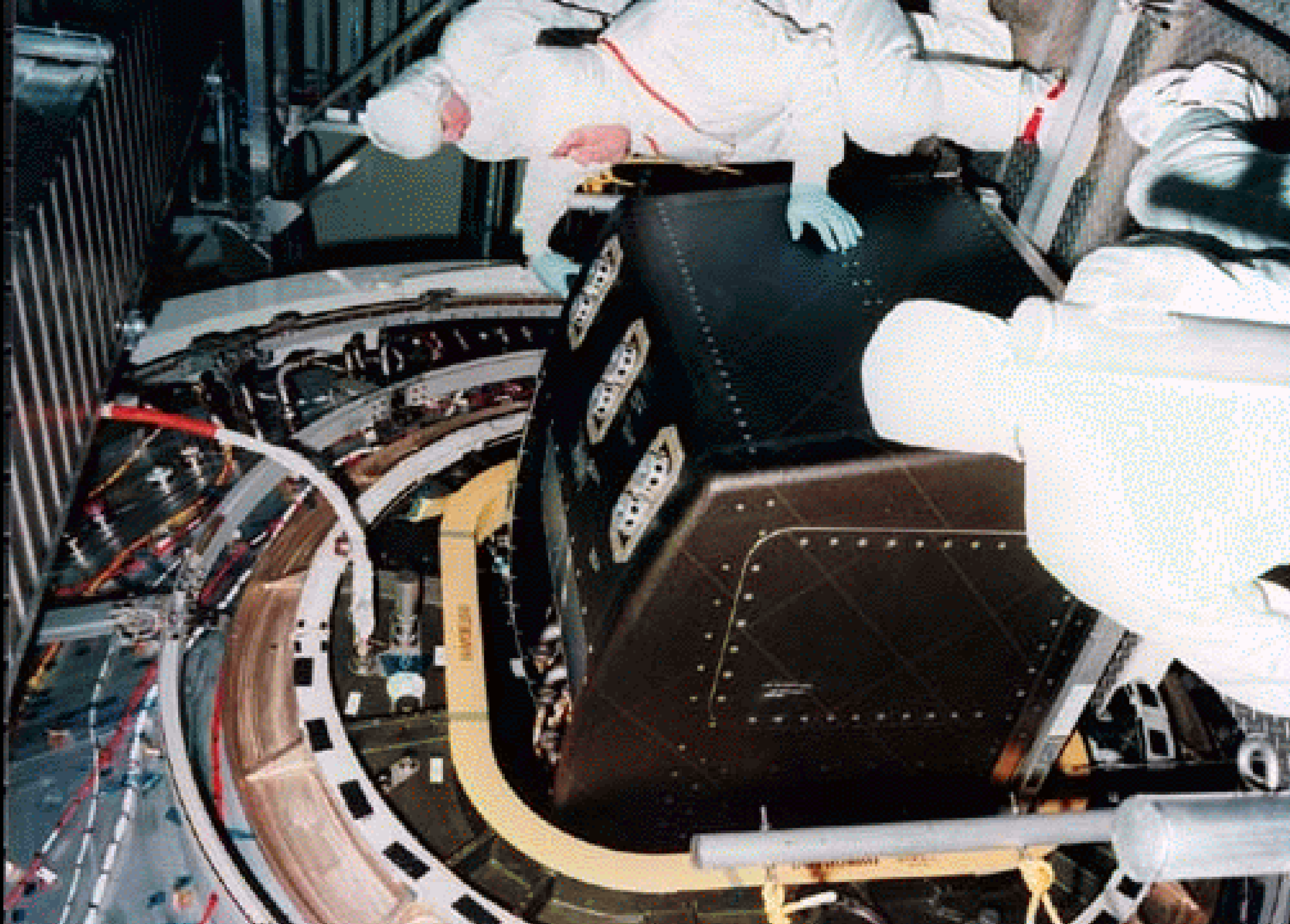
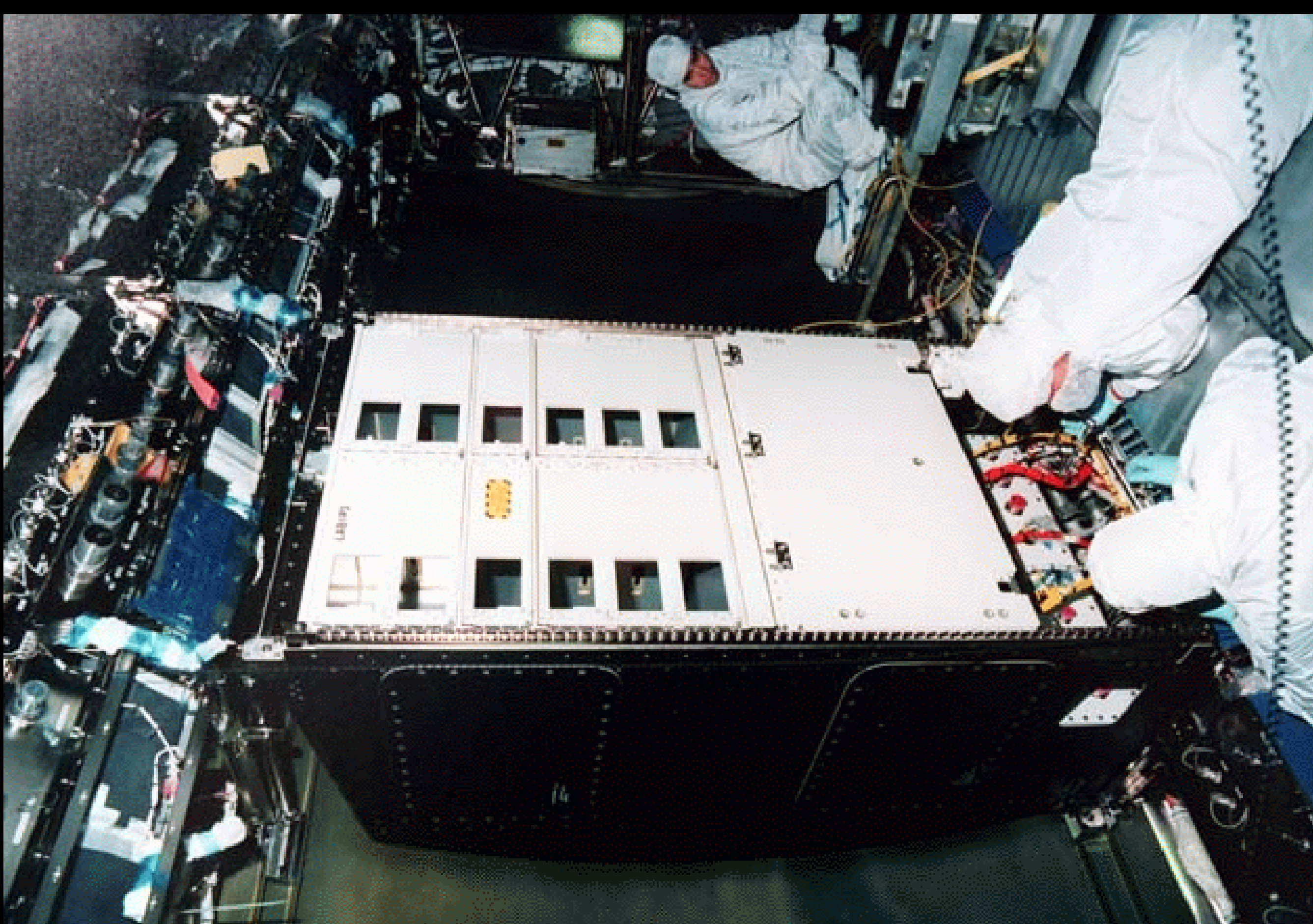


Figure 2.1-24. Station battery subassembly ORU

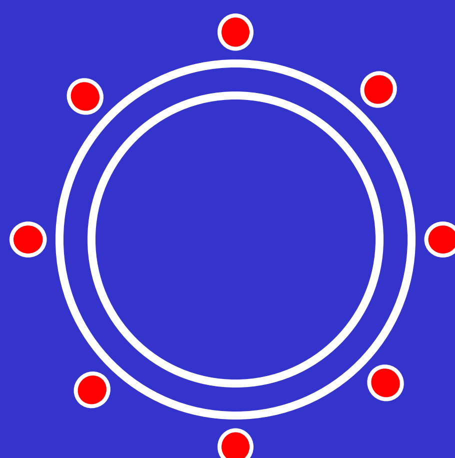
Table 2.1-18. Battery ORU operational limits

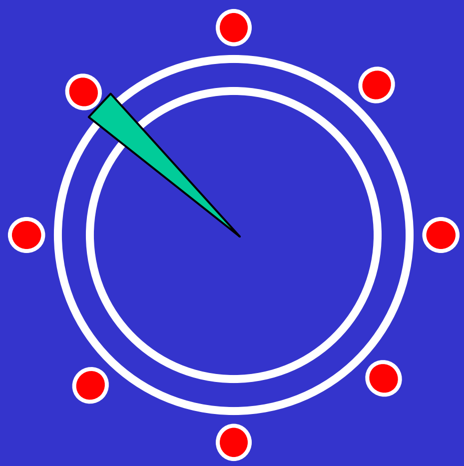
Battery Assembly Parameters	
Nameplate Capacity	81 amp-hours
Depth of Discharge (Nominal Orbit)	SOC decreases by ≤ 35% (nominally) SOC decreases by ≤ 80% (contingency)
Charge Voltage	38.0 to 62.5 V (nominally) 76 to 130 V (BCDU Charge Voltage Limit Setpoint)
Discharge Voltage	≥ 45.5 V (nominally)
Charge Current	50 A (nominally) 61 A (maximum continuous)
Cell Parameters	
Cell Quantity per Battery ORU	38 (connected in series)
Cell Charge Voltage	1.0 to 1.65 V (nominally) ~1.55 V (typically)
Cell Discharge Voltage	1.0 to 1.65 V (nominally)
Cell Charge Current	0 to 73 A (operating range)
Temperature Sensors & Limits	
Thermistors	6 on cell sleeves; 3 on baseplate (Avg. Batt. Temp. is calculated from 4 cell sensors)
Operating Temperature	0 to 10° C (nominally) -5 to 10° C (contingency)
Non-Operating Temperature	-25 to 30° C
BSCCM Operating Temperature	-35 to 50° C
Pressure Sensors & Limits	
Pressure Sensors (Strain Gauges)	4 active sensors (on cells)
Cell Pressure	900 psi (nominal) 1000 psi (max)
Electrical Characteristics	
BSCCM input power	8.1 W (max)
Heater Circuit Power	220 to 236 W (at 120 V) 322 to 342 W (at 145 V)
Heater Power (per Cell)	5.8 to 6.2 W (at 120 V) 8.5 to 9.0 W (at 145 V)

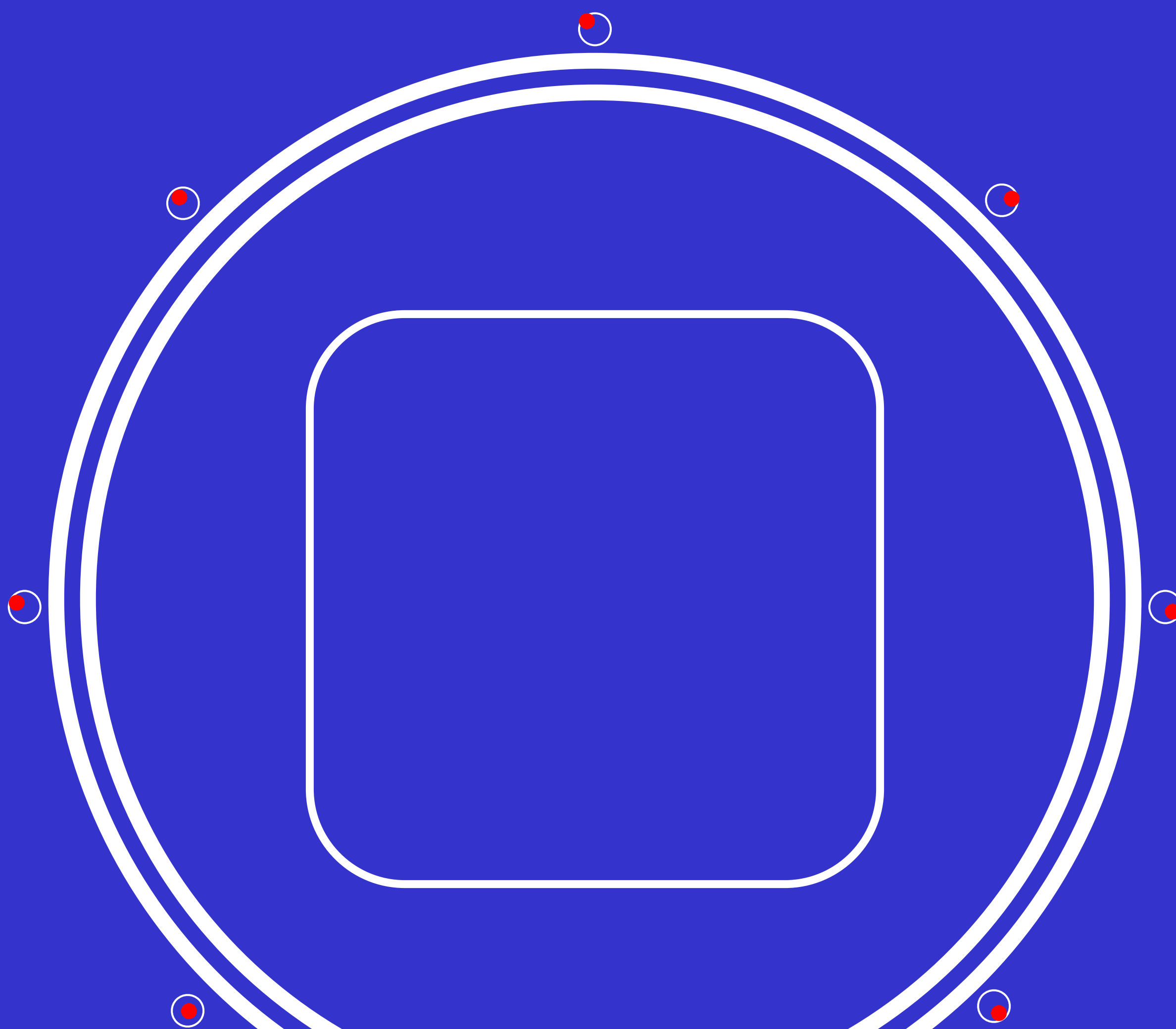


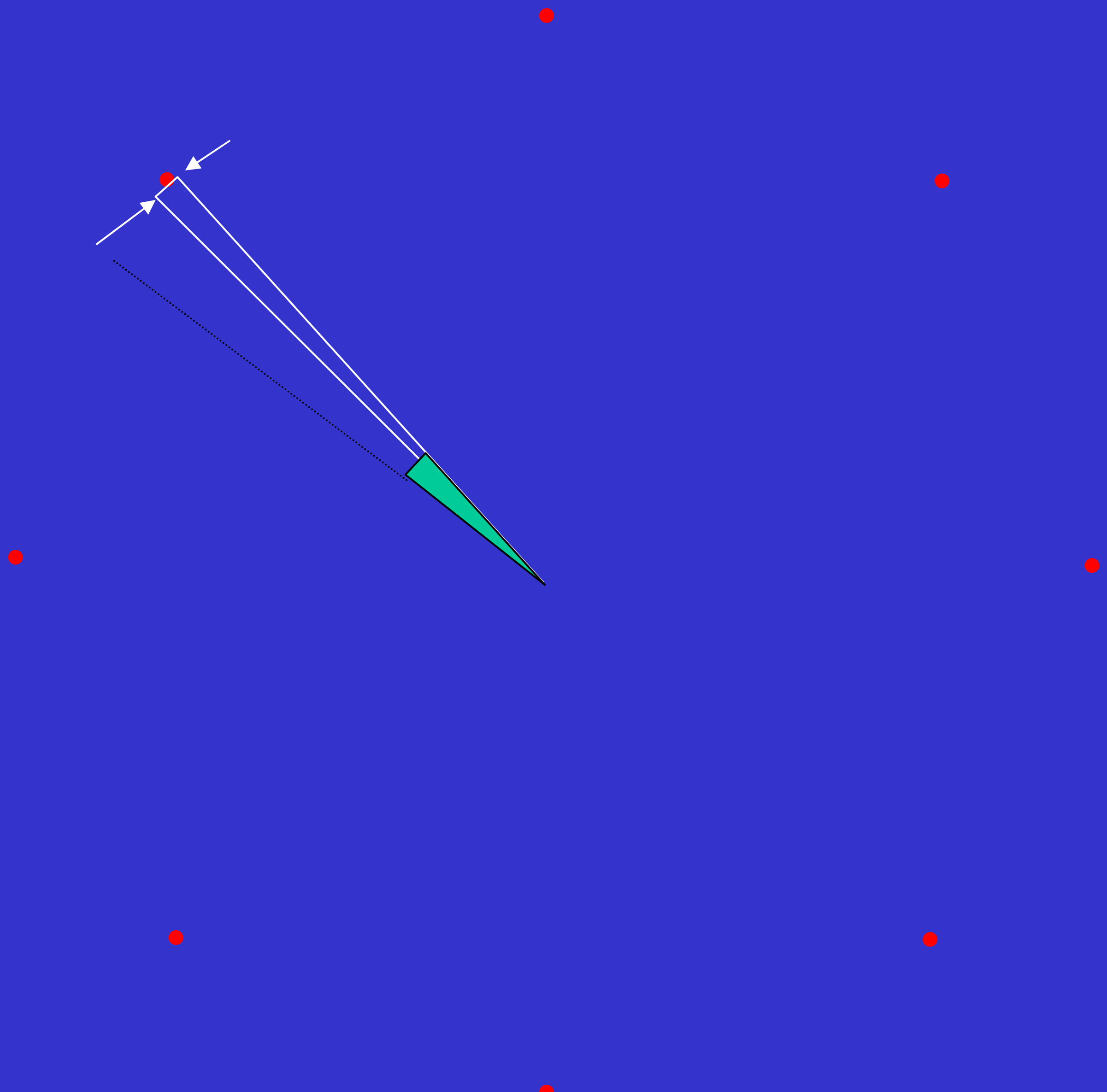


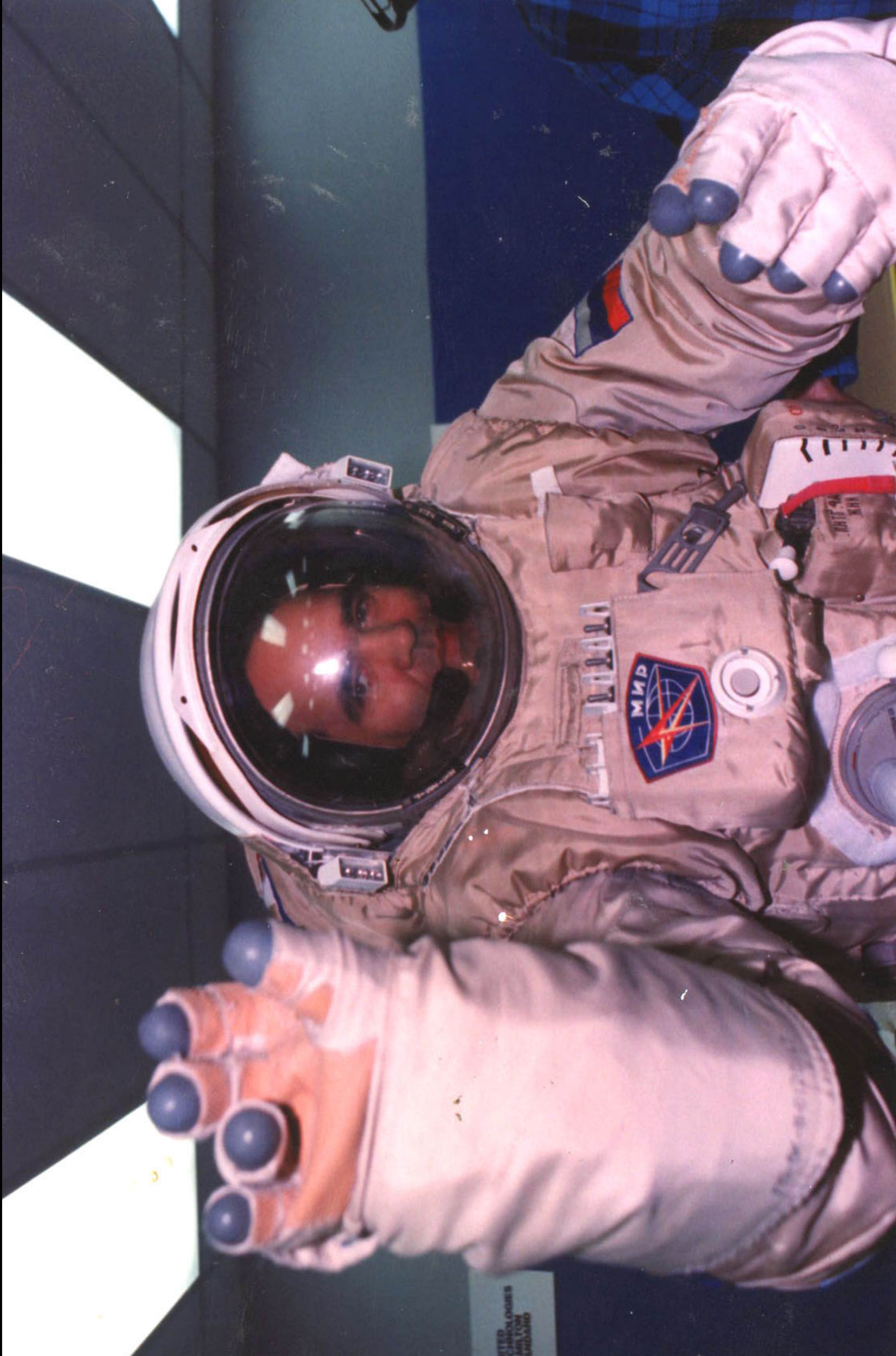

BEVERAGES
SNACKS
FRESH FOOD
COFFEE
BEVERAGES
JUICE
Market Central

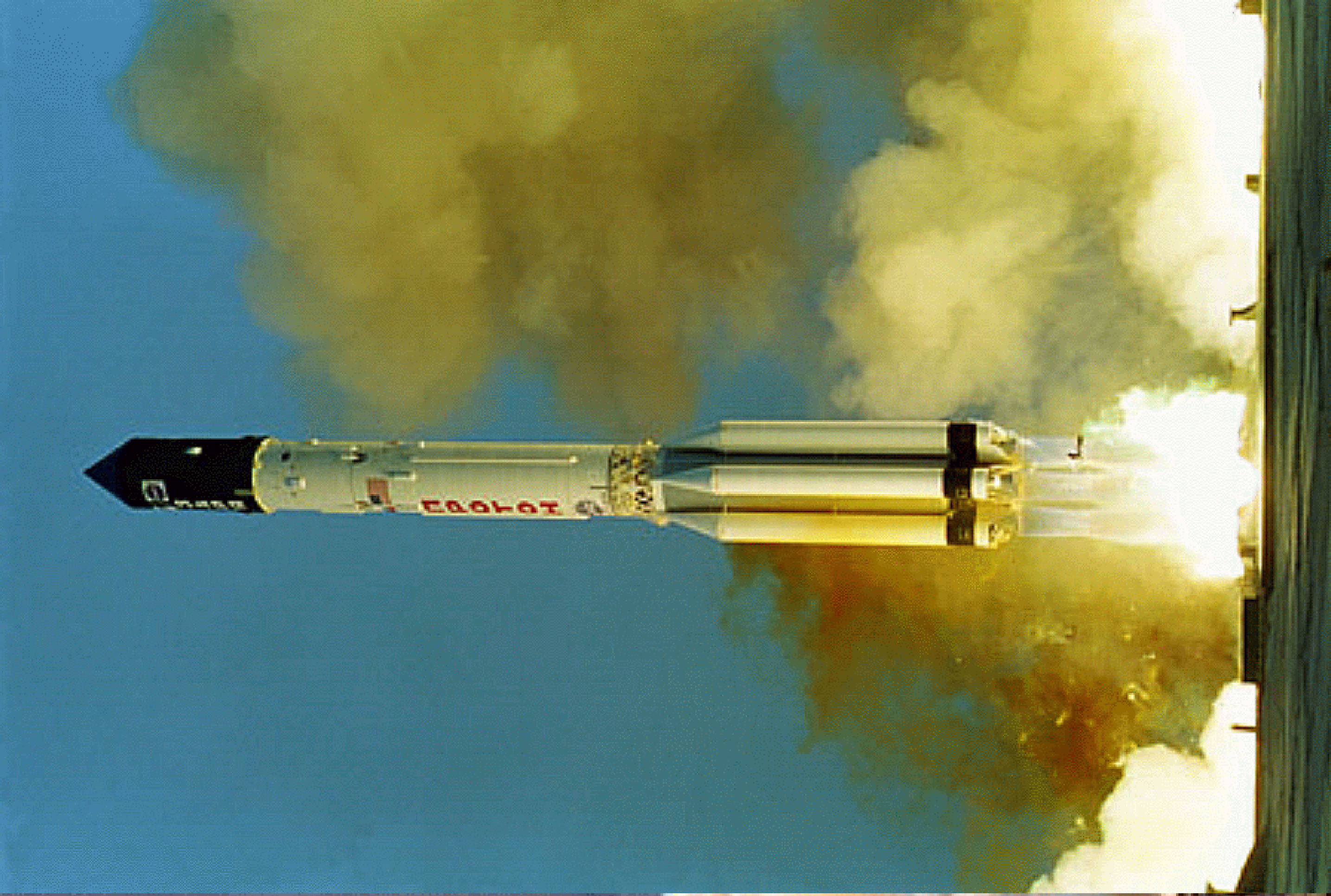


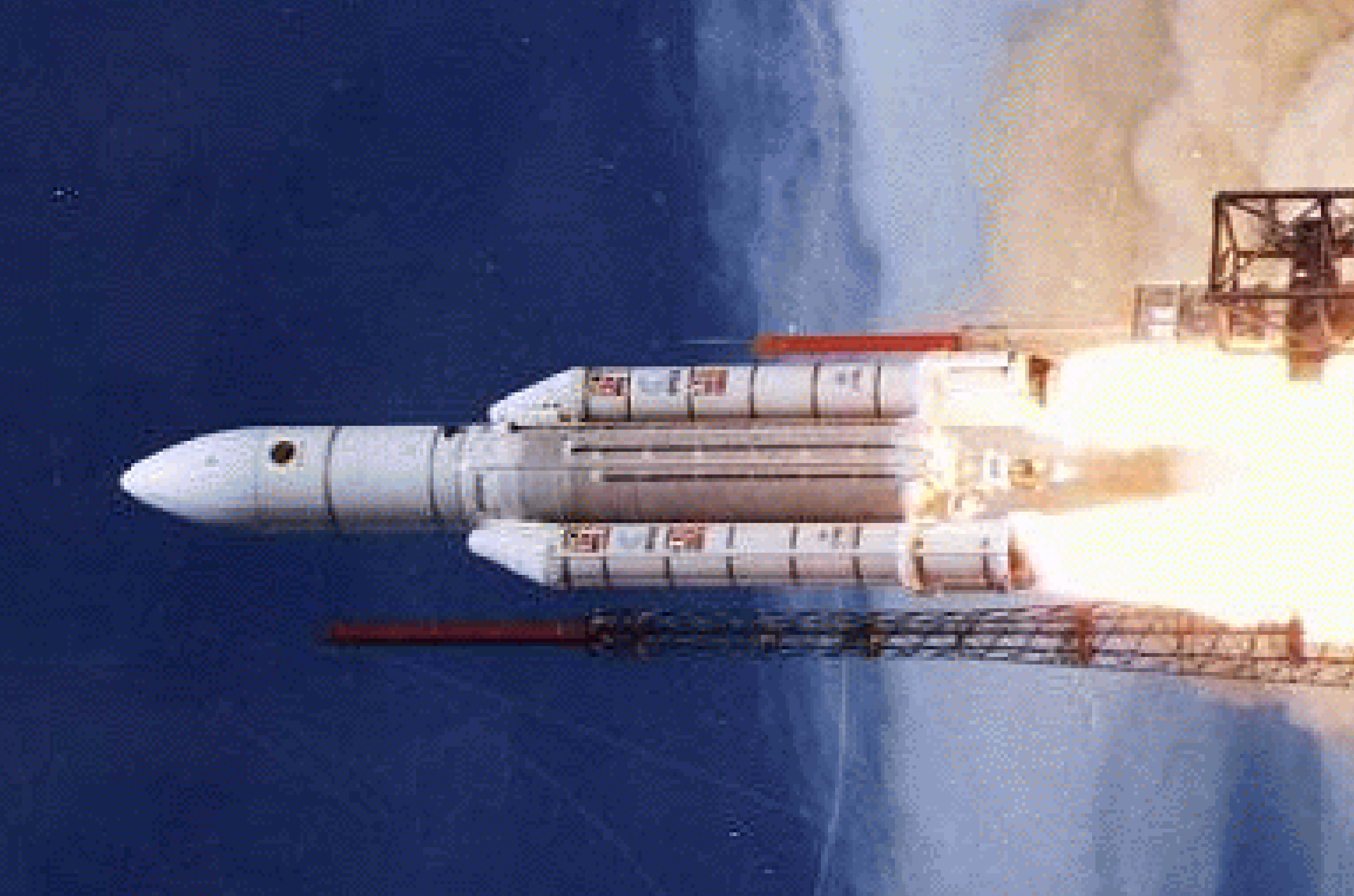


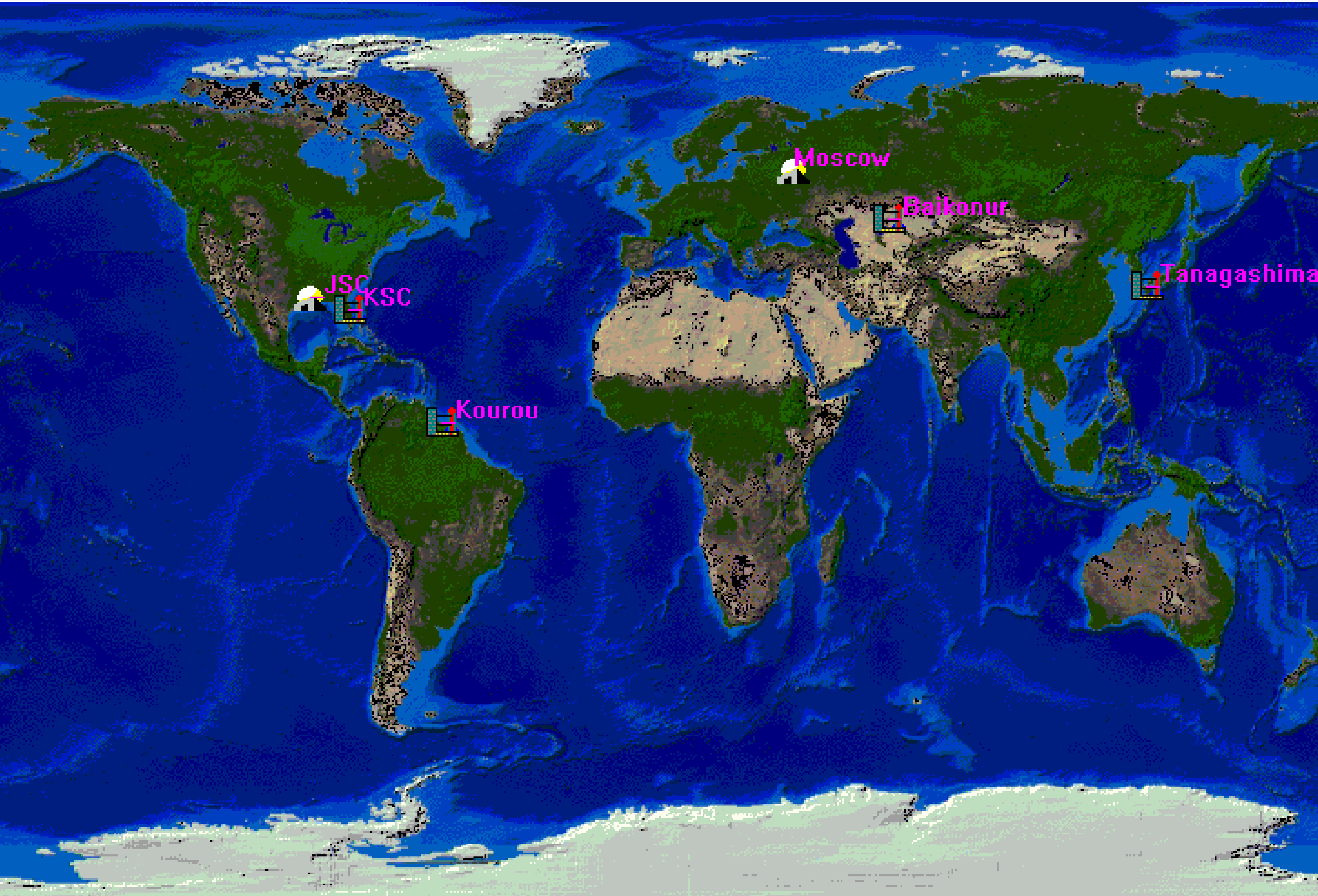





МИР

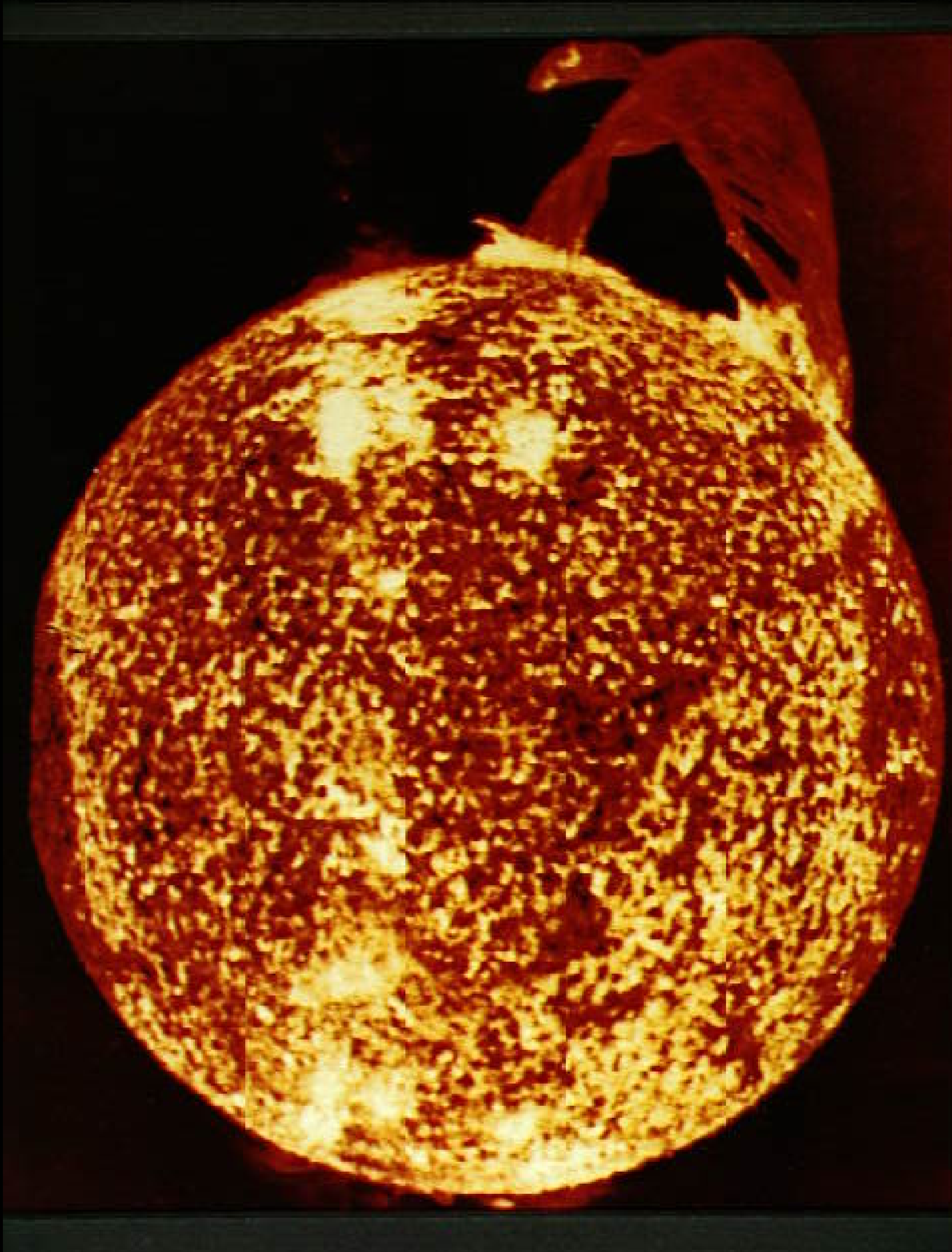





Moscow
Baikonur
Tanagashima
JSC
KSC
Kourou

The weather out there:

(Baby it’s cold outside…)



What's Outside the Hatch?

A Survey of the ISS Space Environment

A presentation to the 10th Annual
International Space Station Educators Conference
February 6, 2002

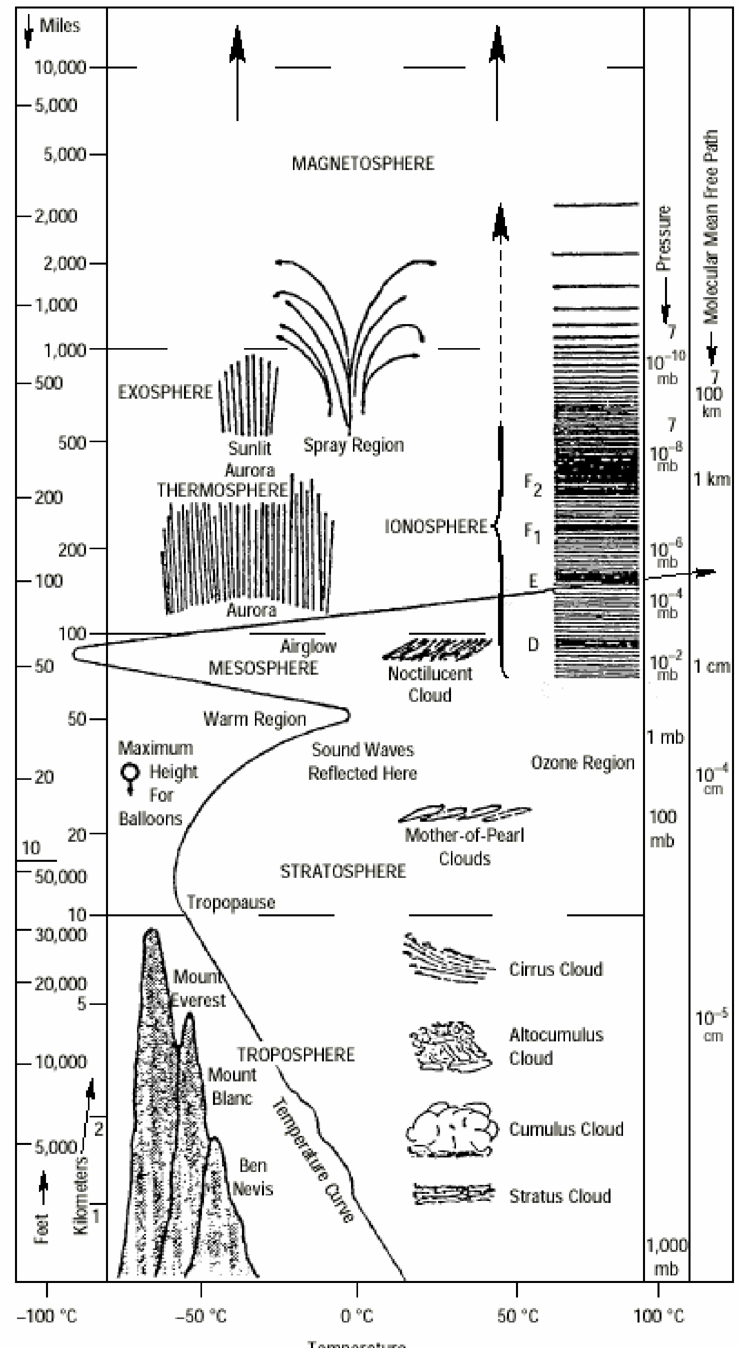
Jeffrey R. Theall, Ph.D.

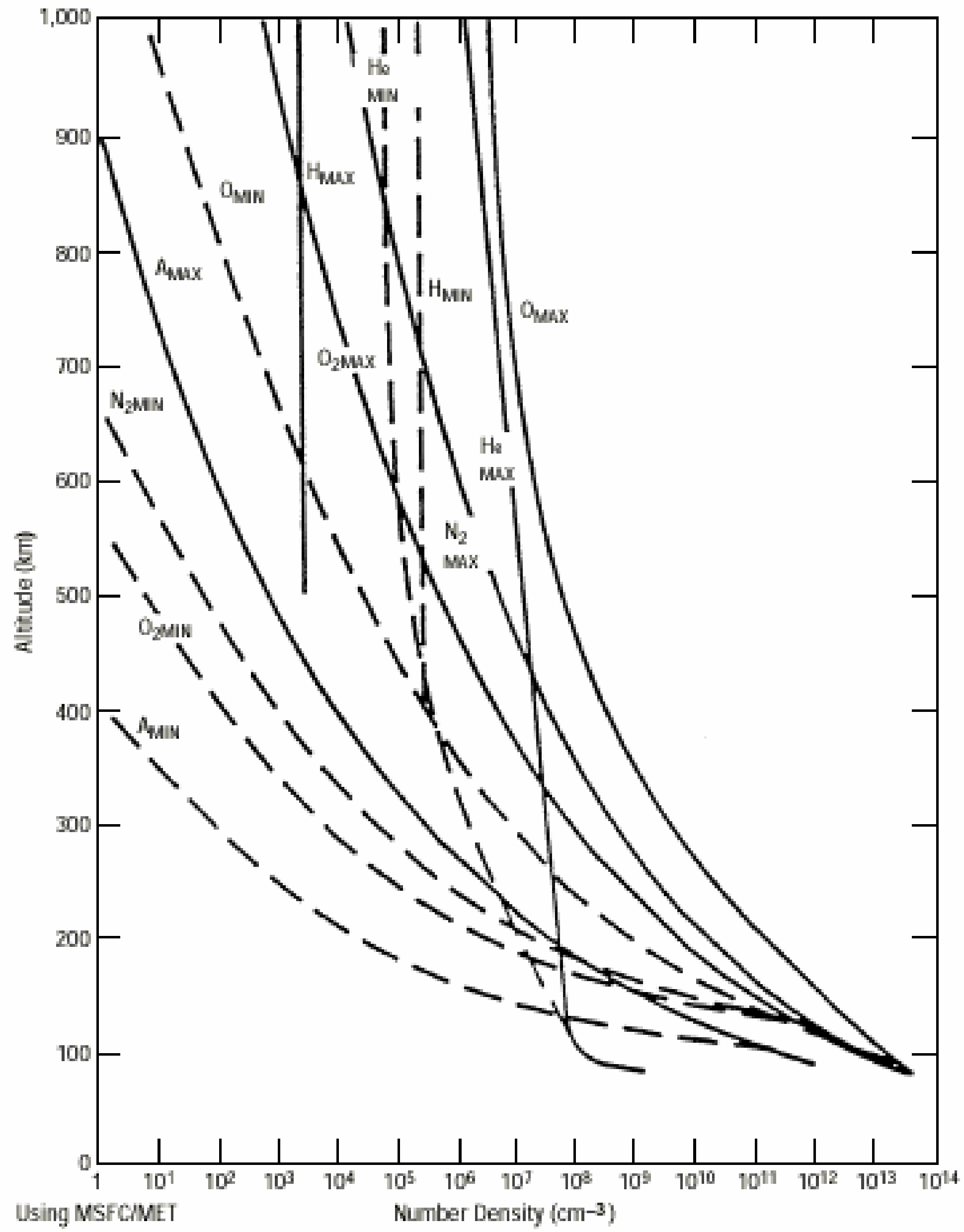
Where is the ISS?

- Orbit: nominally 400 km circular at 51.6
  - actually slightly elliptical, altitude varies on each orbit
  - traverses Earth latitudes -51.6 to +51.6
  - altitude changes with solar cycle

Neutral Gases

Source: NASA Reference Publication 1350
Natural Space Environments
http://see.msfc.nasa.gov

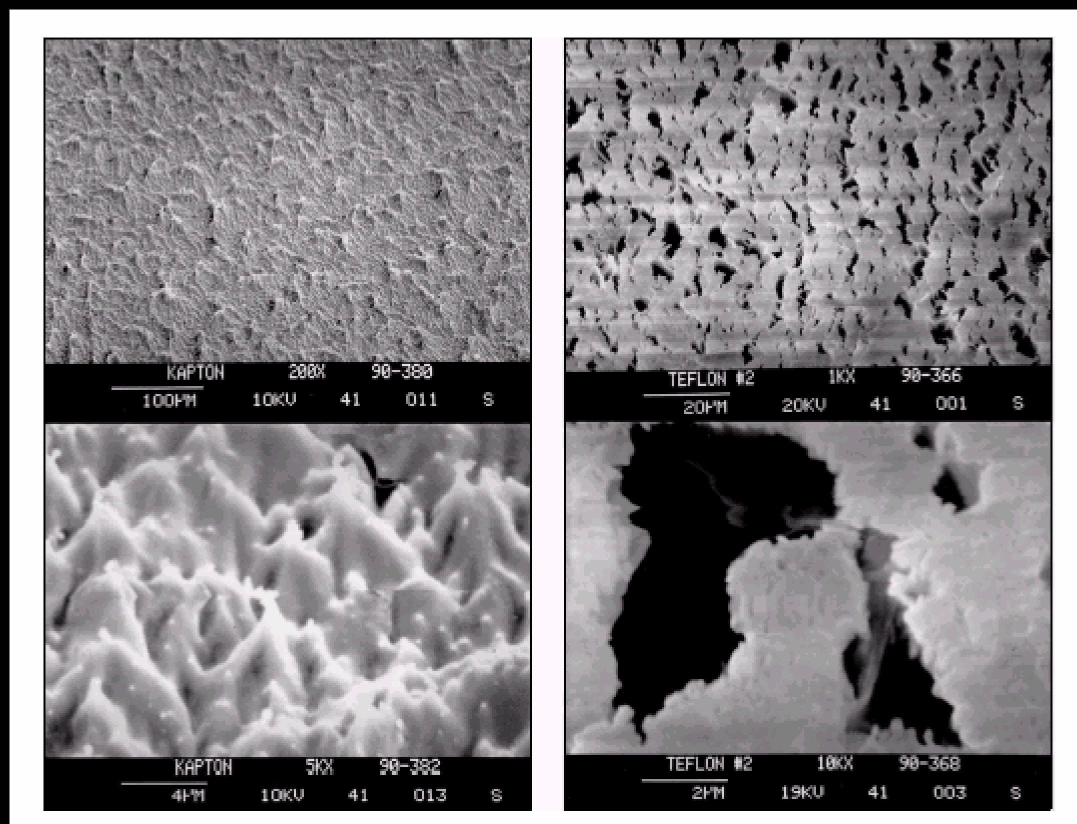


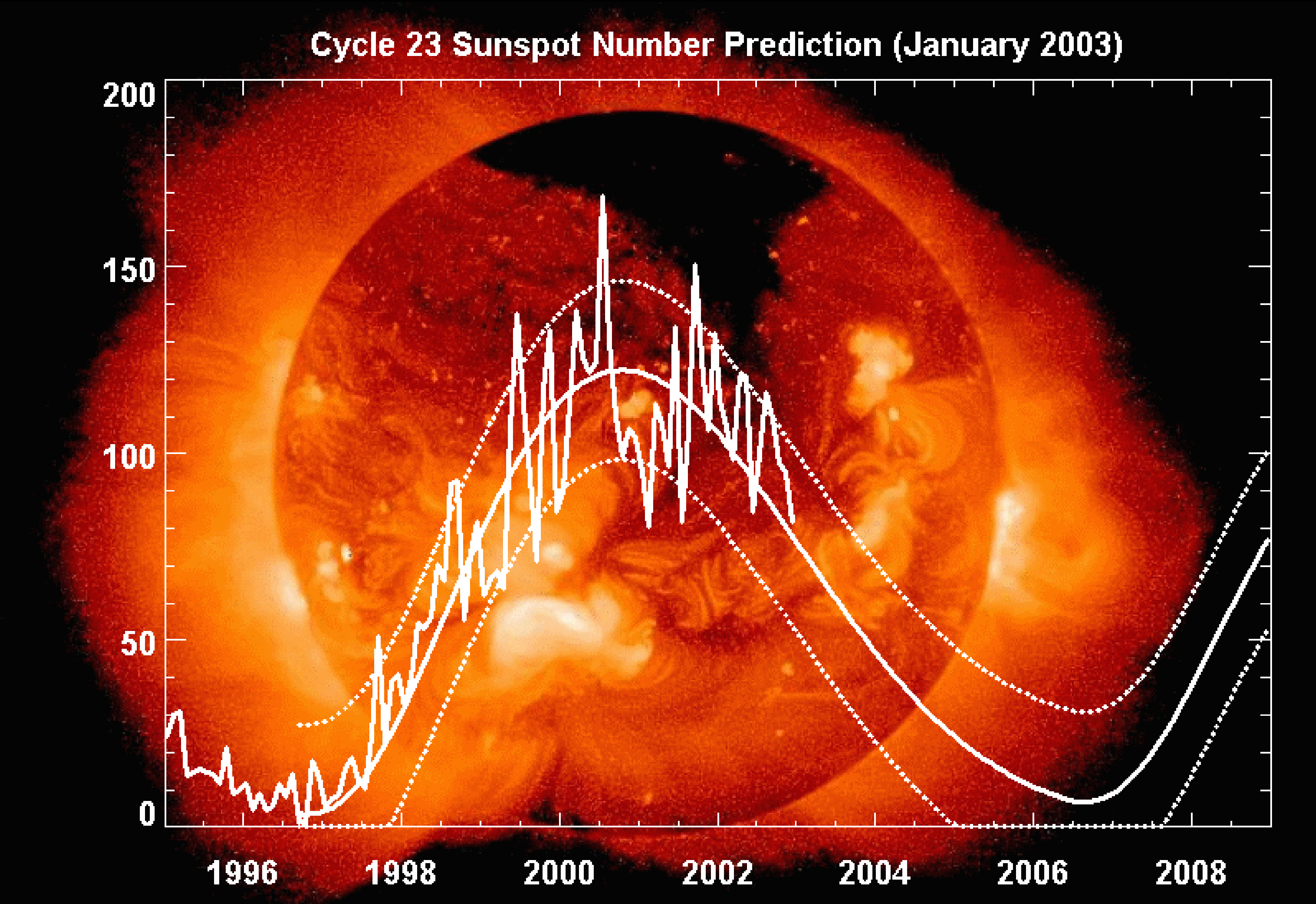


Altitude (km)
1,000
900
800
700
600
500
400
300
200
100
0
1
10¹
10²
10³
10⁴
10⁵
10⁶
10⁷
10⁸
10⁹
10¹⁰
10¹¹
10¹²
10¹³
10¹⁴
Number Density (cm−3)
Using MSFC/MET
He MIN
H MAX
O MIN
A MAX
H MIN
O MAX
O2 MAX
N2 MIN
He MAX
N2 MAX
O2 MIN
A MIN

Source: NASA Reference Publication 1390
Failures and Anomalies Attributed to the
Natural Space Environment

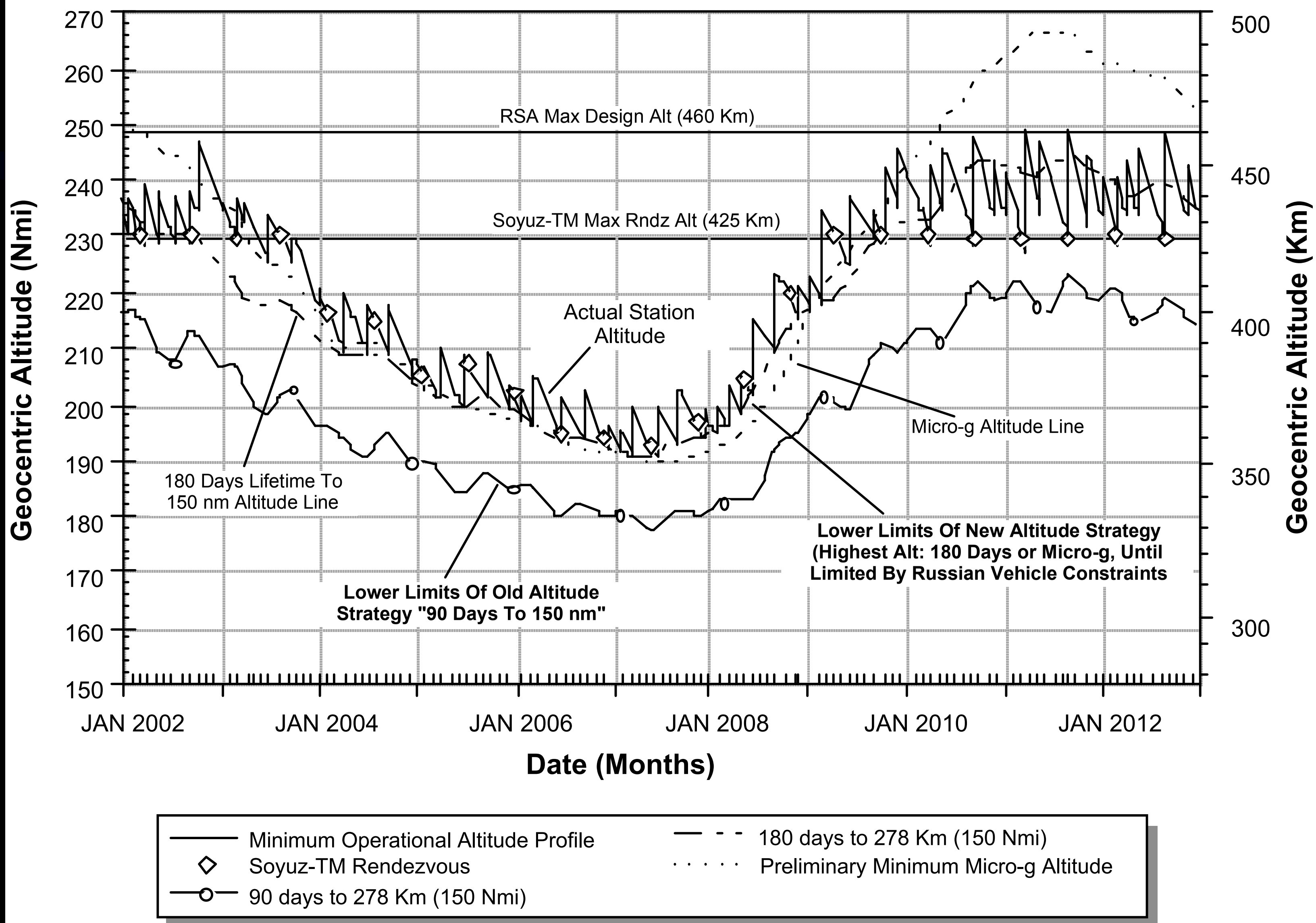
AO Erosion



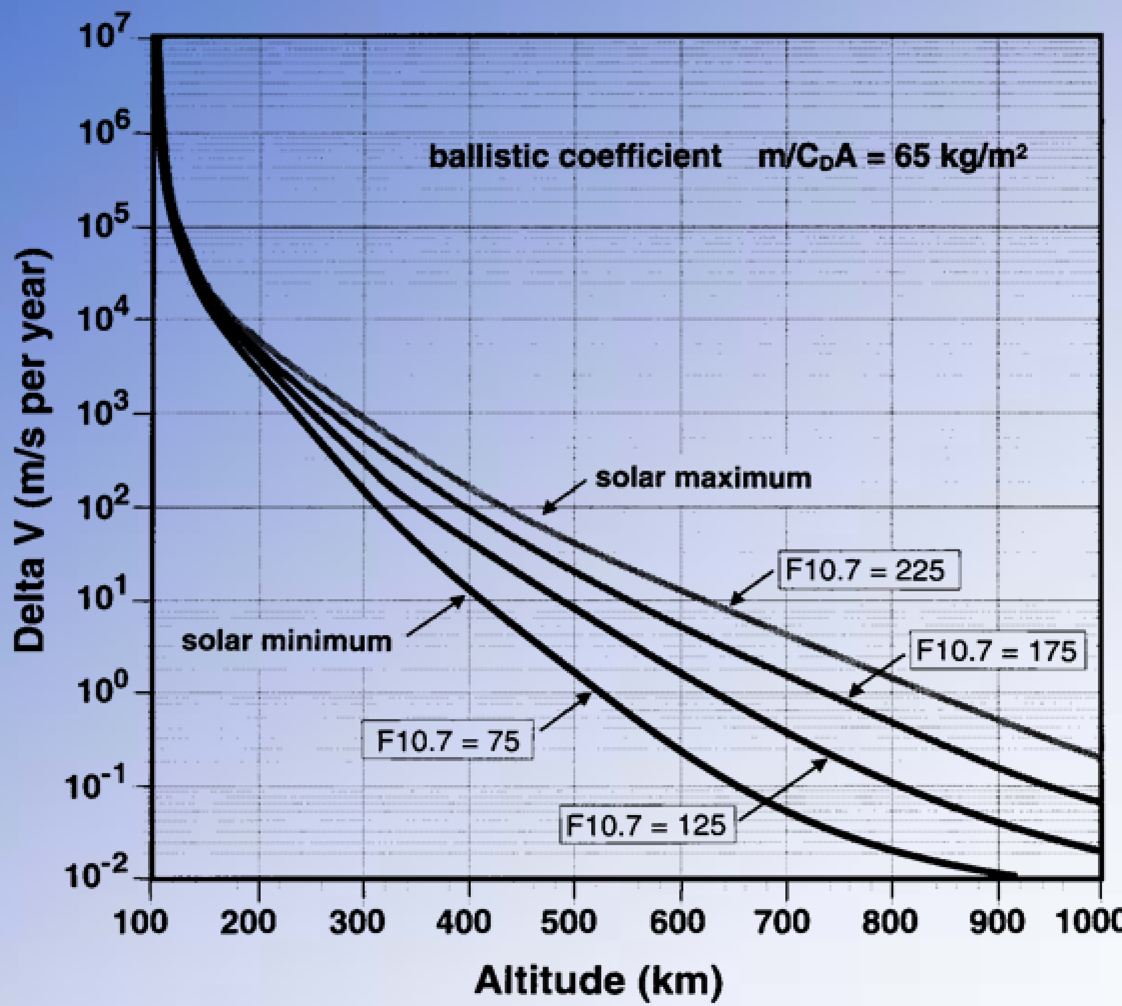

Cycle 23 Sunspot Number Prediction (January 2003)
200
150
100
50
0
1996
1998
2000
2002
2004
2006
2008

Space Station Altitude Strategy

Post Assembly Complete Time Frame

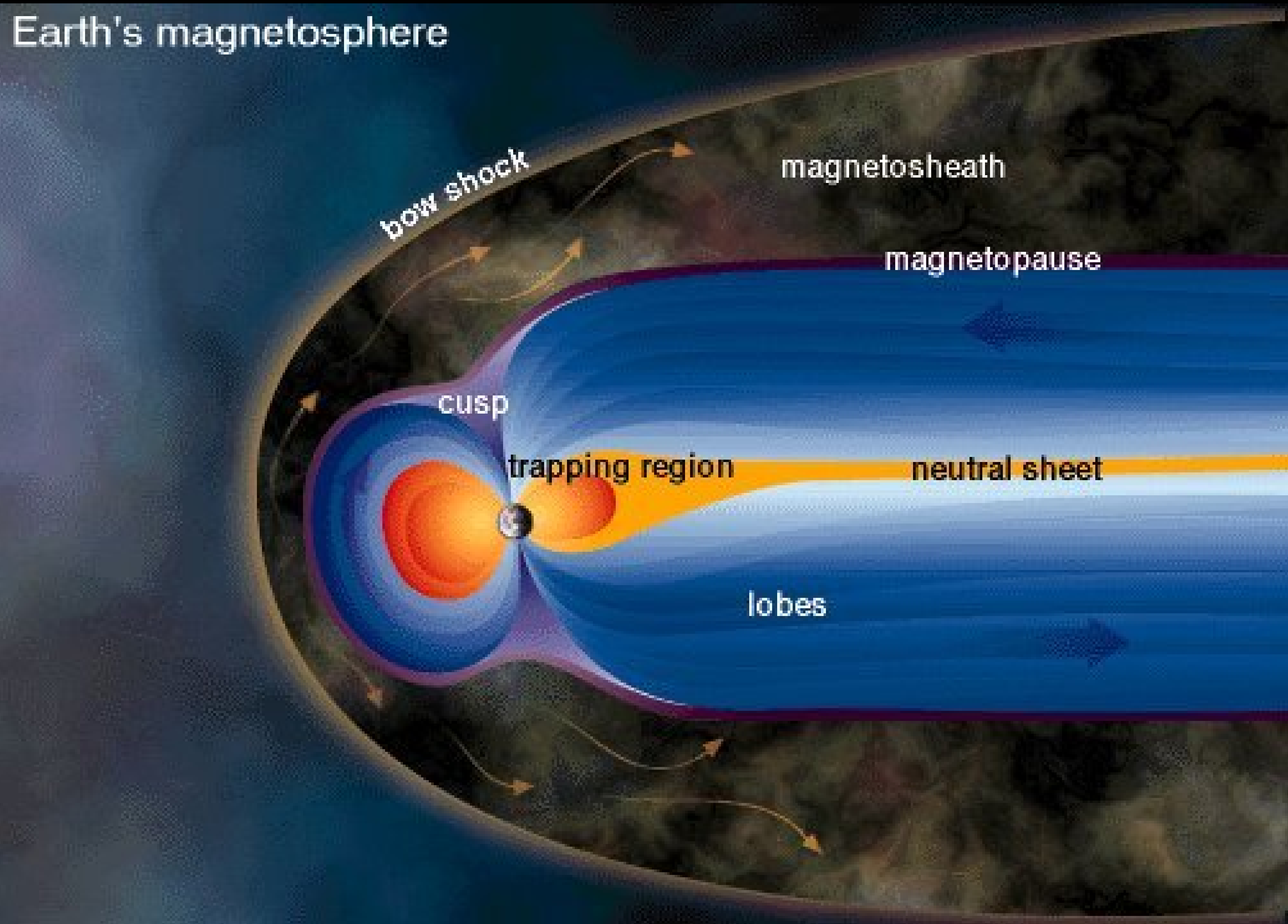


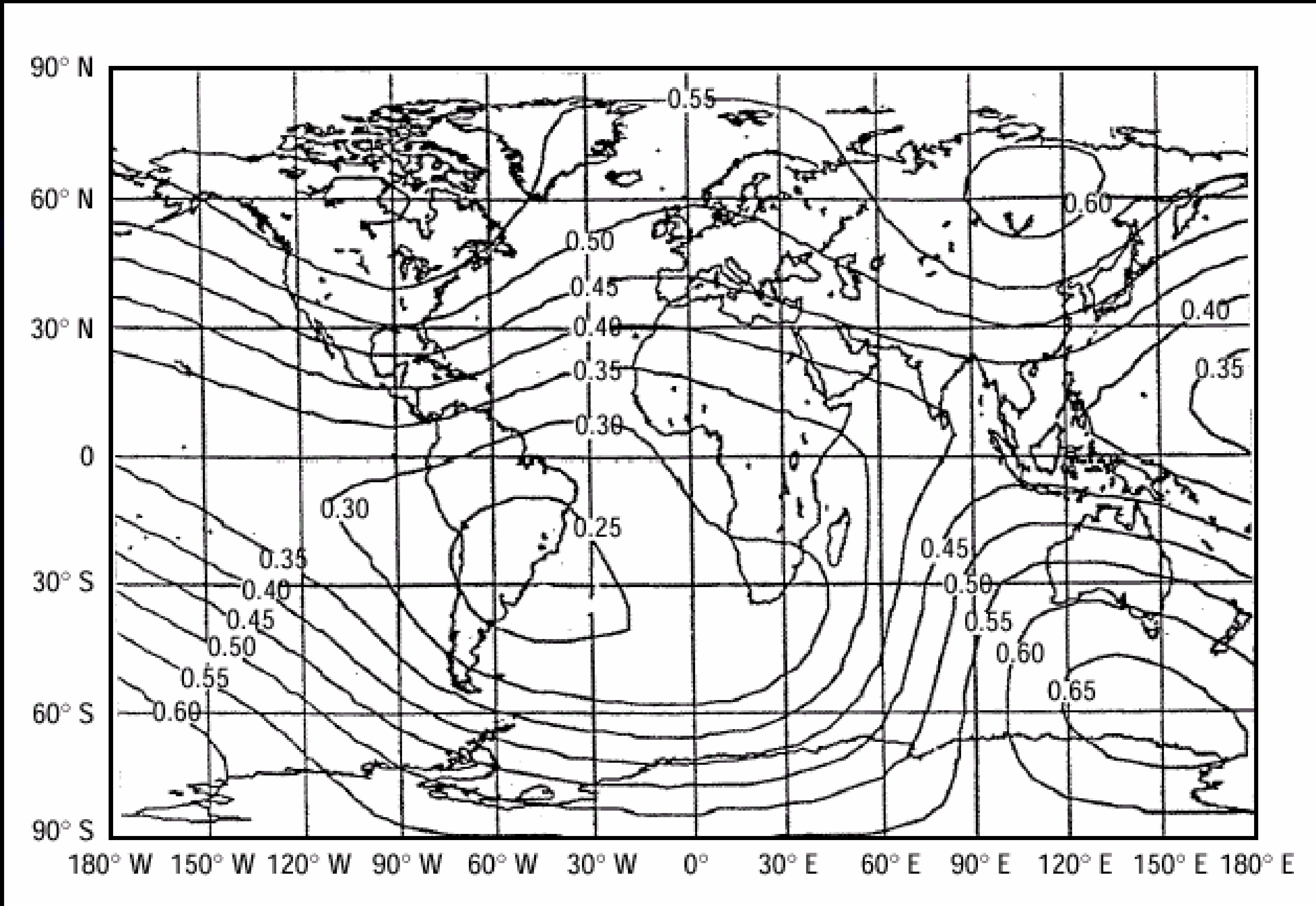
Orbit Altitude/Drag Maintenance



Ionizing Radiation

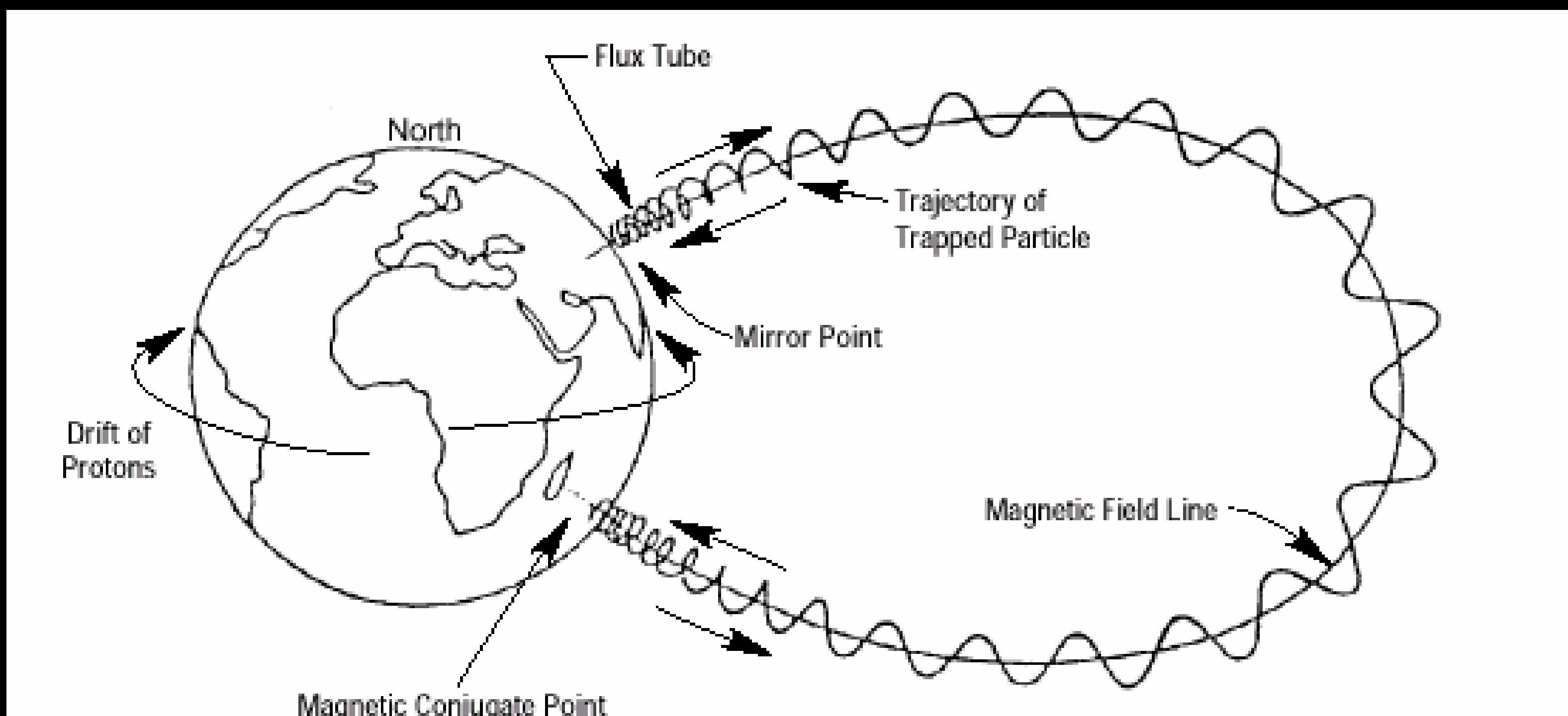
- Three types:
  - Trapped high energy particles
  - Galactic cosmic rays
  - Solar flare proton events
- IR affects spacecraft electronics
- IR poses a danger to astronauts


Earth's magnetosphere
bow shock
magnetosheath
magnetopause
cusp
trapping region
neutral sheet
lobes



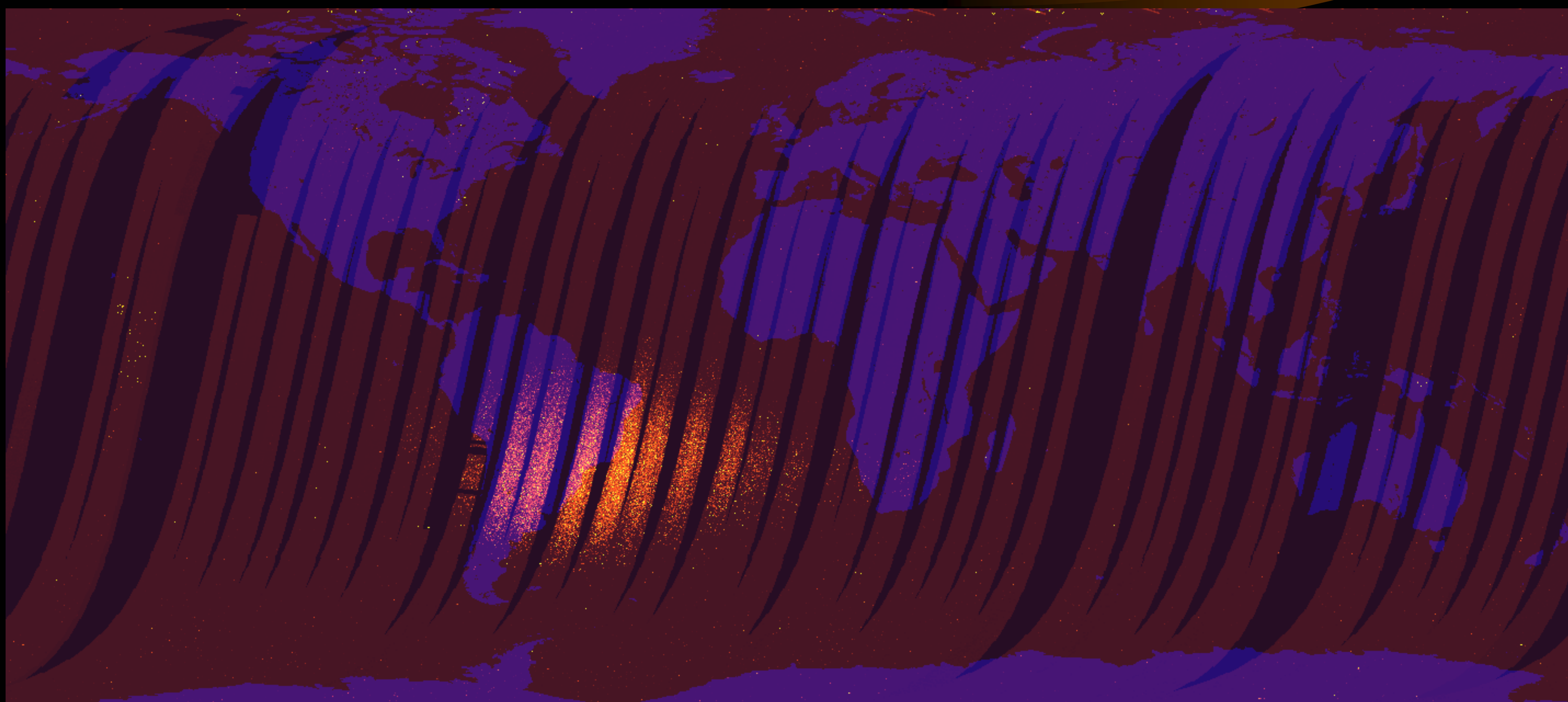
Geomagnetic Field at Sea Level

Trapped Particles



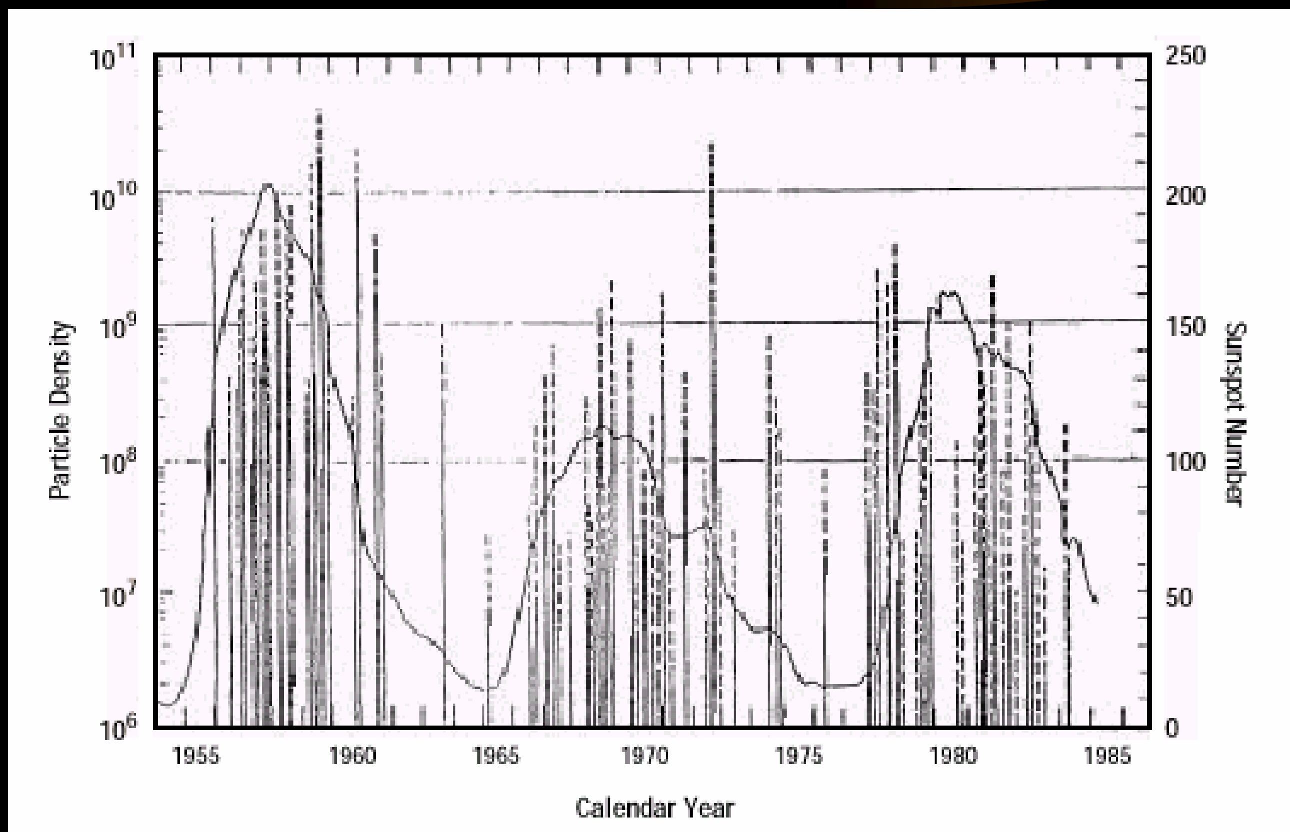
Aurora Borealis from the Shuttle

South Atlantic Anomaly



Source: Multi-angle Imaging SpectroRadiometer (MISR) instrument data from NASA's Terra spacecraft
http://visibleearth.nasa.gov

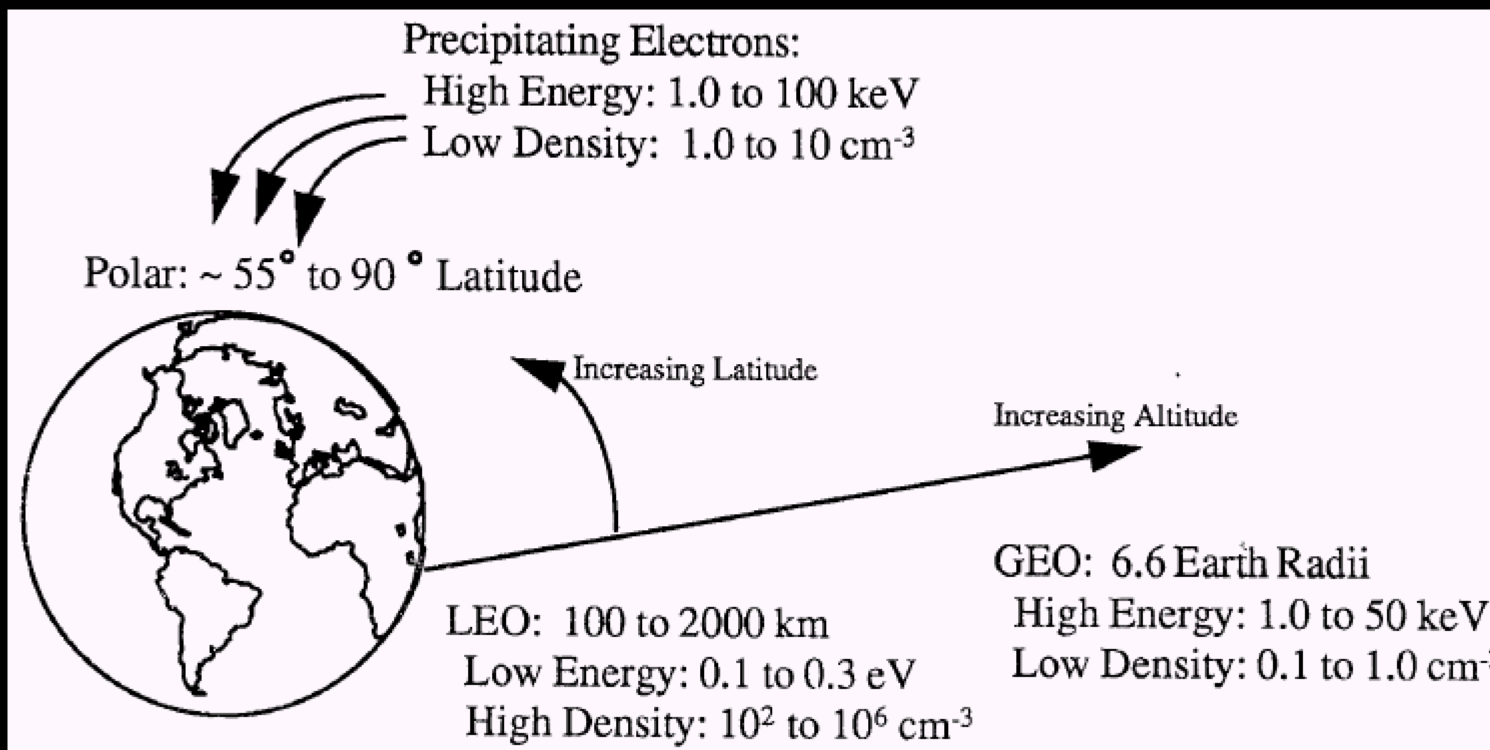
Solar Flare Proton Events

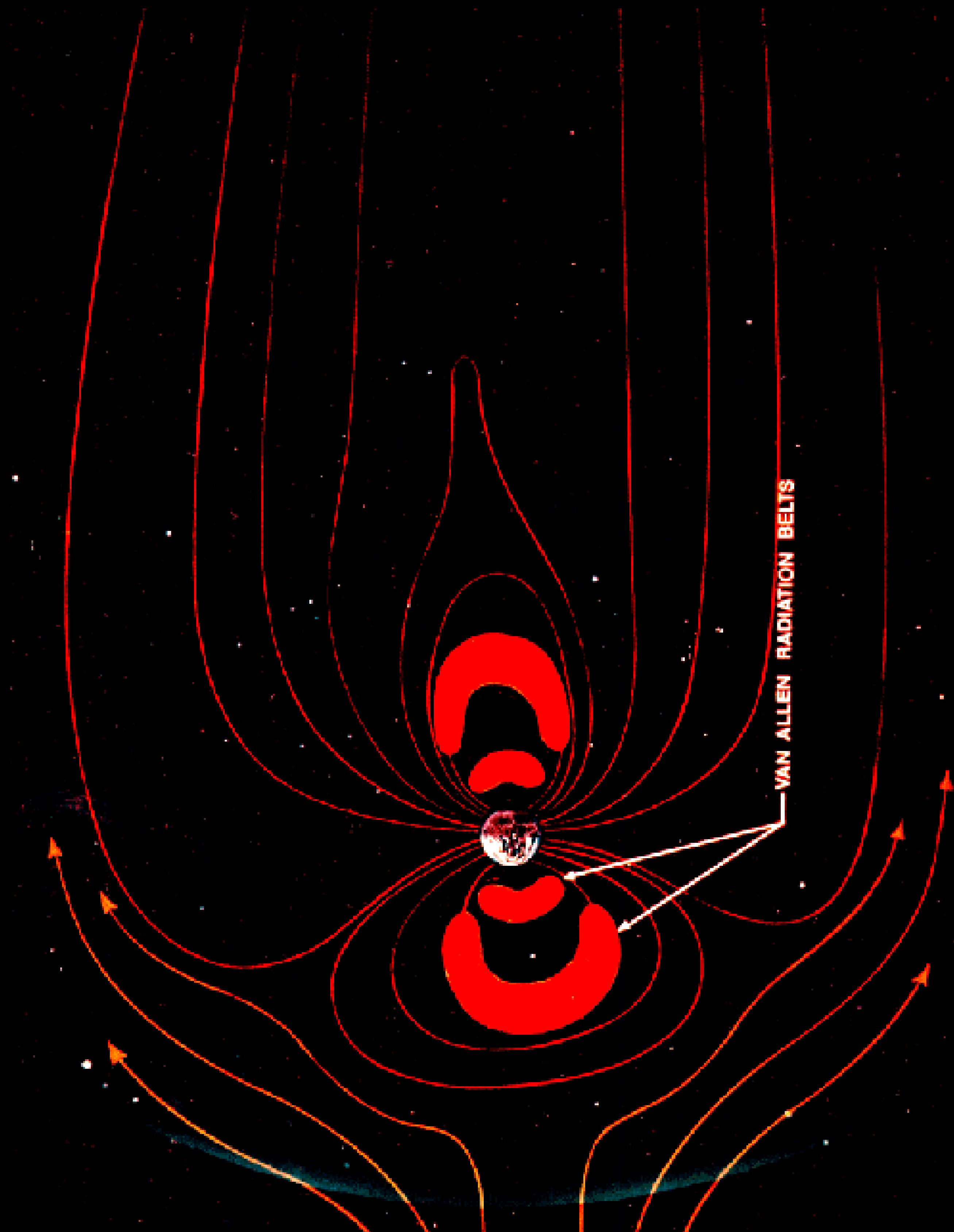


Plasma Environment

- Above 90 km photodissociation produces plasma
- Plasma causes spacecraft charging which leads to arc discharging events that damage the spacecraft

Properties of Natural Space Plasmas

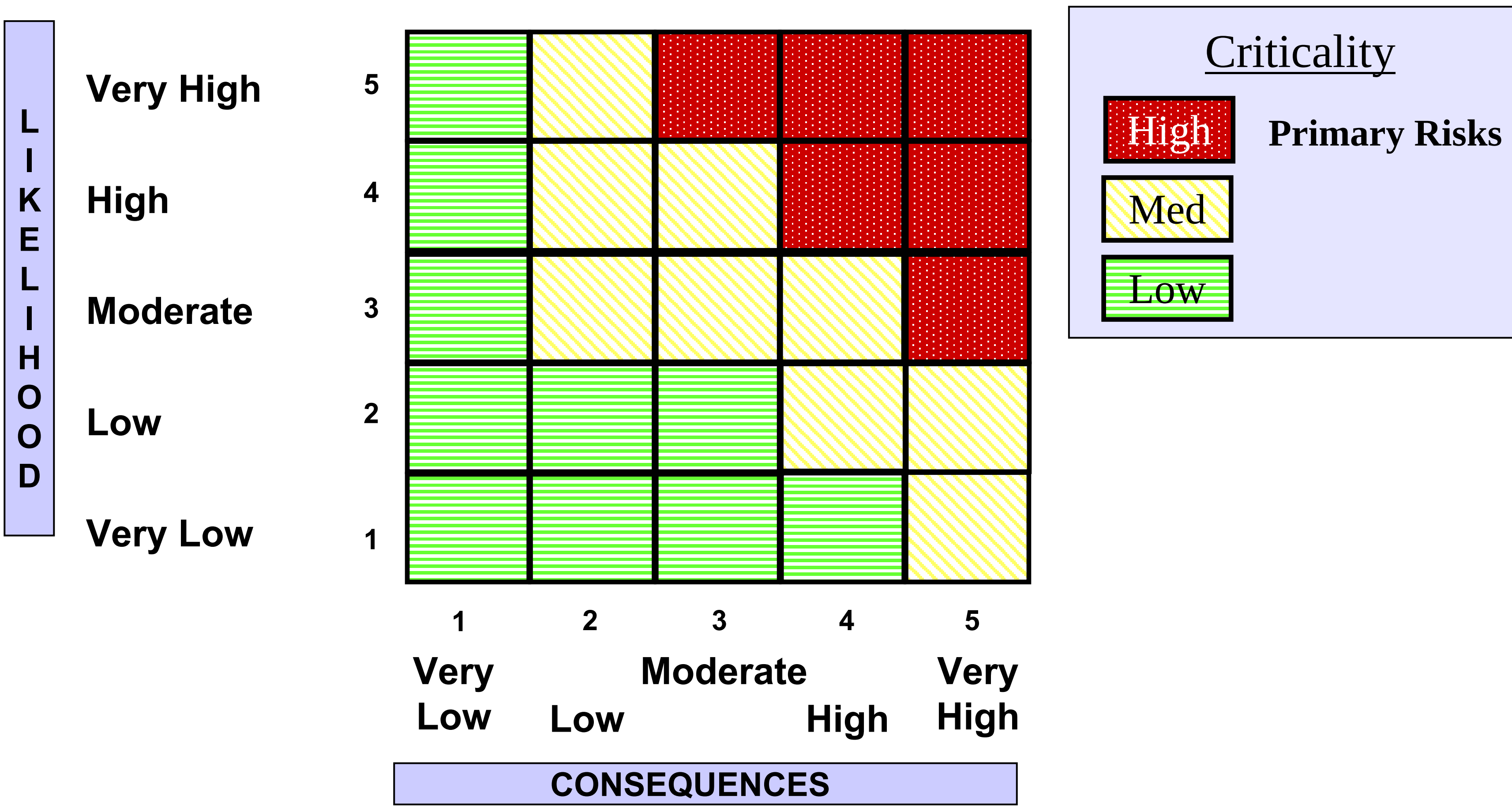



VAN ALLEN RADIATION BELTS

Thermal Environment

- Three sources of radiant thermal energy
  - Incoming solar radiation - full spectrum
  - Reflected solar
  - Earth outgoing long-wave radiation (OLR)
- Uneven radiant loading over an orbit
- Spacecraft are both hot and cold

5x5 Risk Matrix



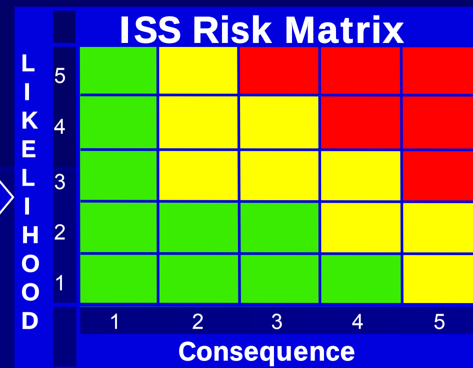
ISS PROGRAM RISK MANAGEMENT

Likelihood Rating

5	Very Likely	Expected to happen in the life of the program. Controls are missing or insufficient.	~ 1 in 10*
4	Likely	Likely to happen in the life of the program. Controls have significant limitations or uncertainty.	~ 1 in 100*
3	Possible	Could happen in the life of the program. Controls exist, with some limitations or uncertainty.	~ 1 in 1,000*
2	Unlikely	Unlikely to happen in the life of the program, but not expected. Controls have minor limitations or uncertainty.	~ 1 in 10,000*
1	Highly Unlikely	Extremely remote possibility that it will happen in the life of the program. Strong controls in place.	~ 1 in 100,000*

* Rough order of magnitudes are offered for guidance when quantification is available. Probabilities may not apply or be appropriate to all risks.

ISS Risk Matrix



Mitigation

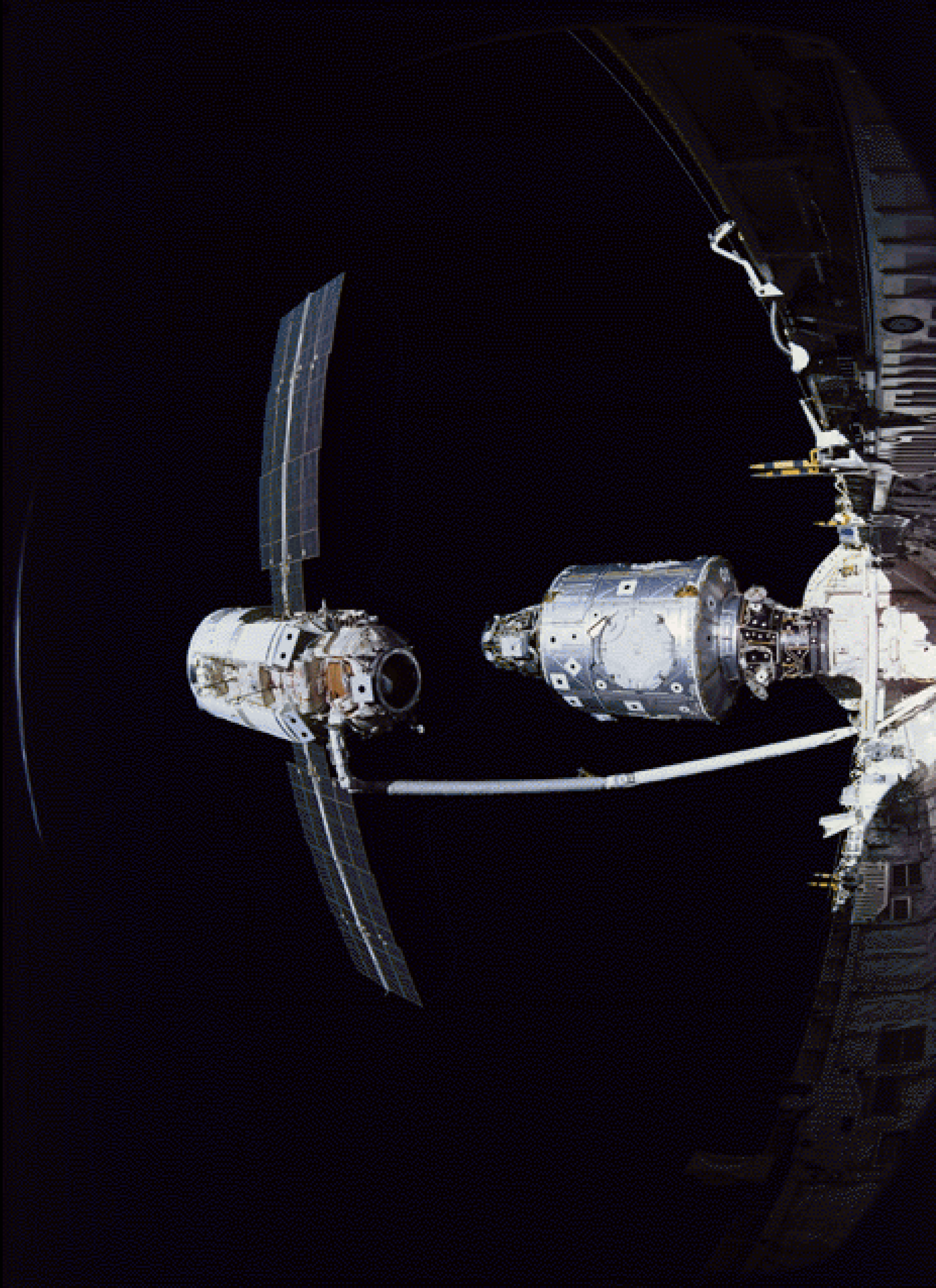
- High – Implement new process(es) or change baseline plan(s)
- Medium – Aggressively manage; consider alternative process
- Low – Manage within normal processes; monitor

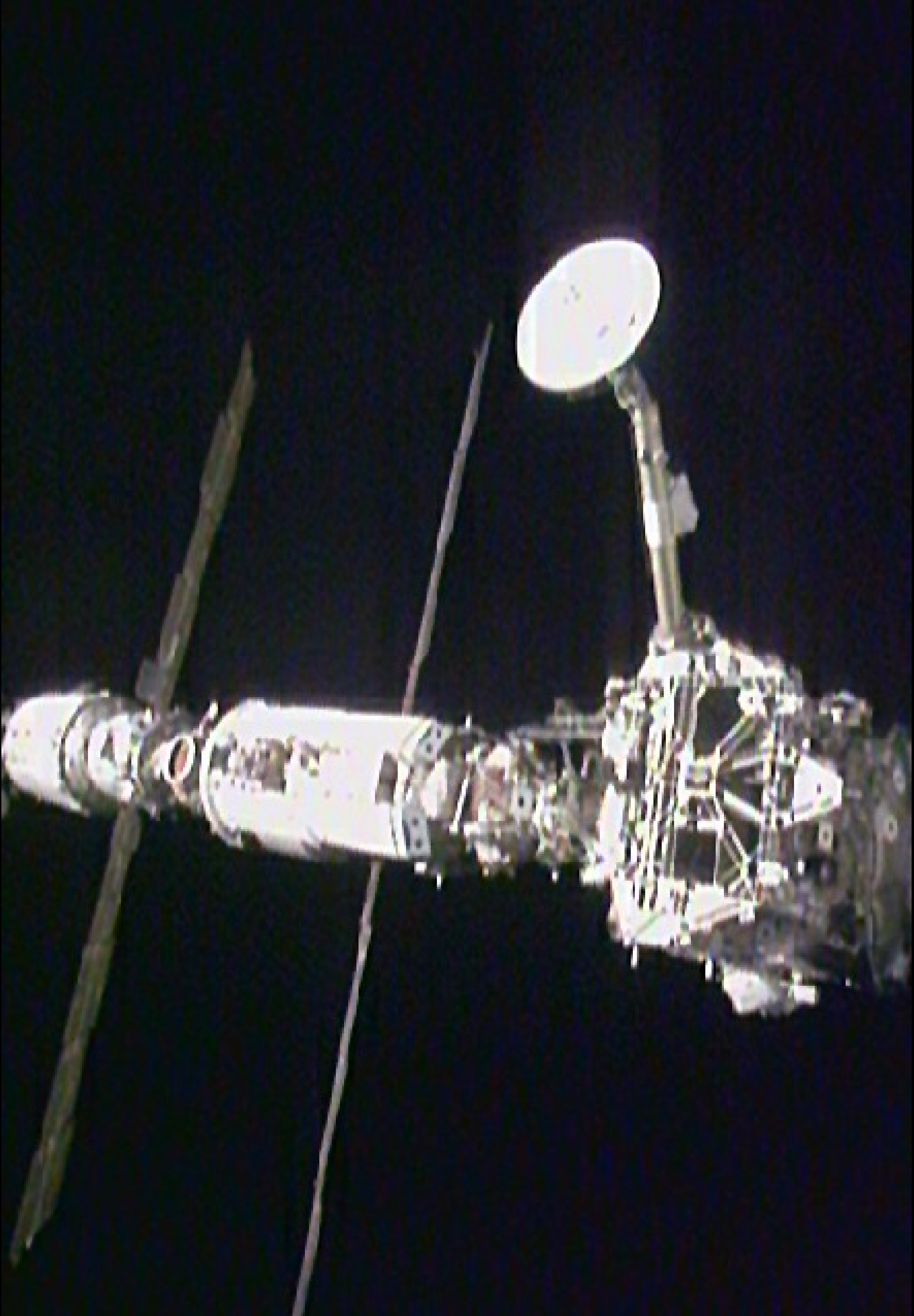
Consequence Rating		1 Minor	2 Moderate	3 Significant	4 Major	5 Catastrophic
Technical	Mission Success / Operational Performance	Minor or no impact to mission objectives Nominal Execution of Mission Minor reduction in performance Minor or no impact to design or operating margins	Failure to meet any single mission objective Operating in a degraded state Moderate reduction in performance Can handle within design or operating margins	Significant impact to mission objectives Operational Workarounds available Significant reduction in performance Significant loss in design or operating margin	Loss of multiple mission objectives Loss of any non-criticial system or function Major increase in flight operations timeliness or complexity Major degradation in performance Loss of all design or operating margin Planned De-Crewing	Loss of entire mission Loss of any critical system or function No alternatives exist Emergency Evacuation
	Safety	First Aid or minor injury Damage to non-flight critical assets	Short-term injury, illness, or impairment Loss of non-flight critical assets	Long-term or mission-significant injury, incapacitation, or impairment Damage to major flight system or element, or ground facility	Permanent or serious injury, incapacitation, or impairment Loss of major system or element or ground facility	Loss of Life Loss of ISS
Programmatic	Cost - Score by cost of mitigating risk	Minimal impact (<$100K) or <5% increase	Moderate impact ($100K up to $1M) or 5-10% increase	Significant impact ($1M up to $10M) or >10% up to 15% increase	Major impact ($10M up to $50M) or >15% up to 20% increase	Major impact (> $50M) or >20% increase
	Schedule	Minor or no impact	Can handle with schedule reserve, no impact to key project milestone or critical path	Project milestone slip No impact to Program critical path	Impact to Program milestone and/or Program critical path	Cannot meet program milestone(s)

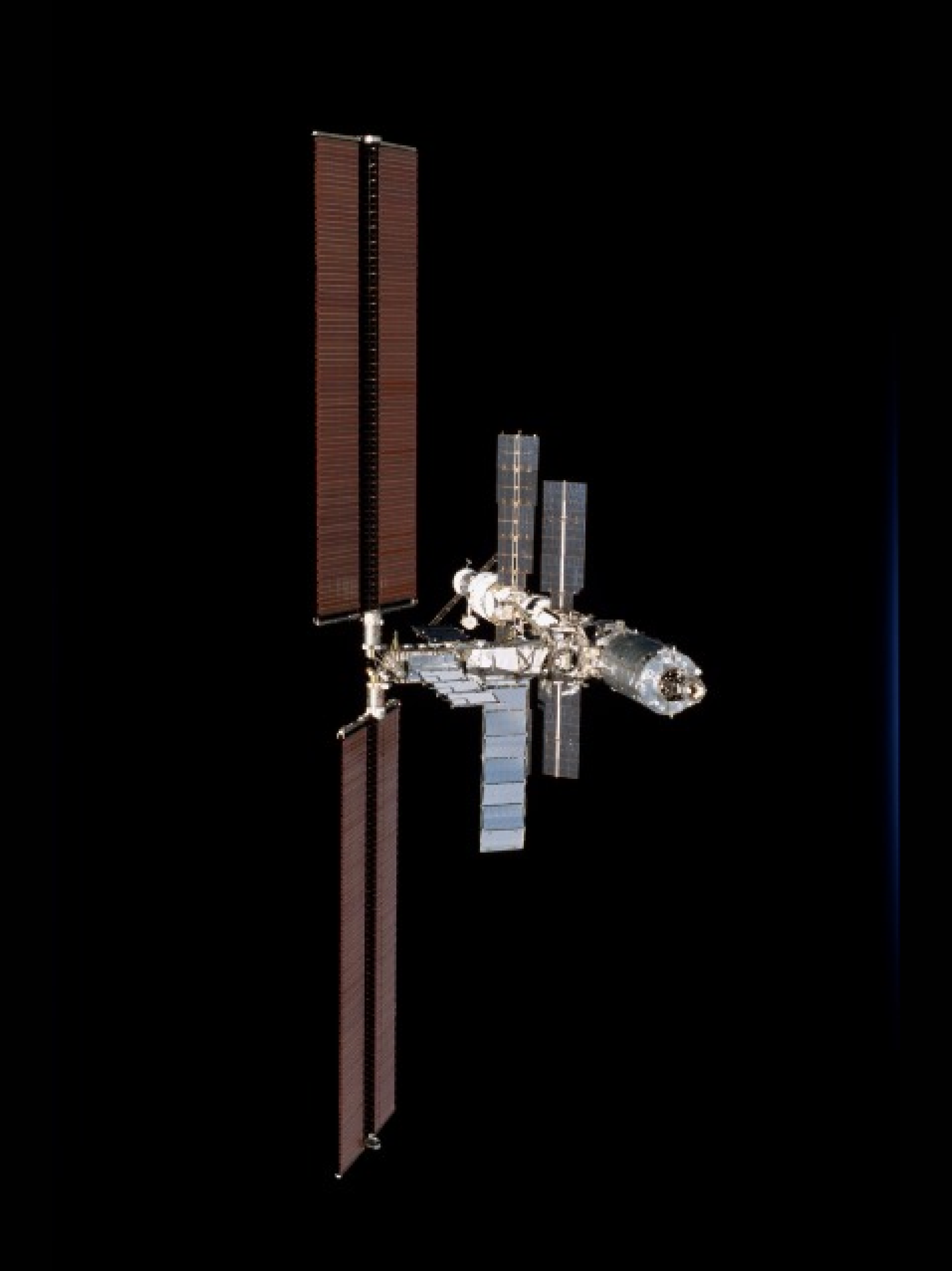
Note: This card is used as a framework for determining a likelihood and consequence for a risk. Risk identification should take precedence over agreeing to a score. Score is relative to the risk's highest elevation; i.e. sub-org, org, or Program

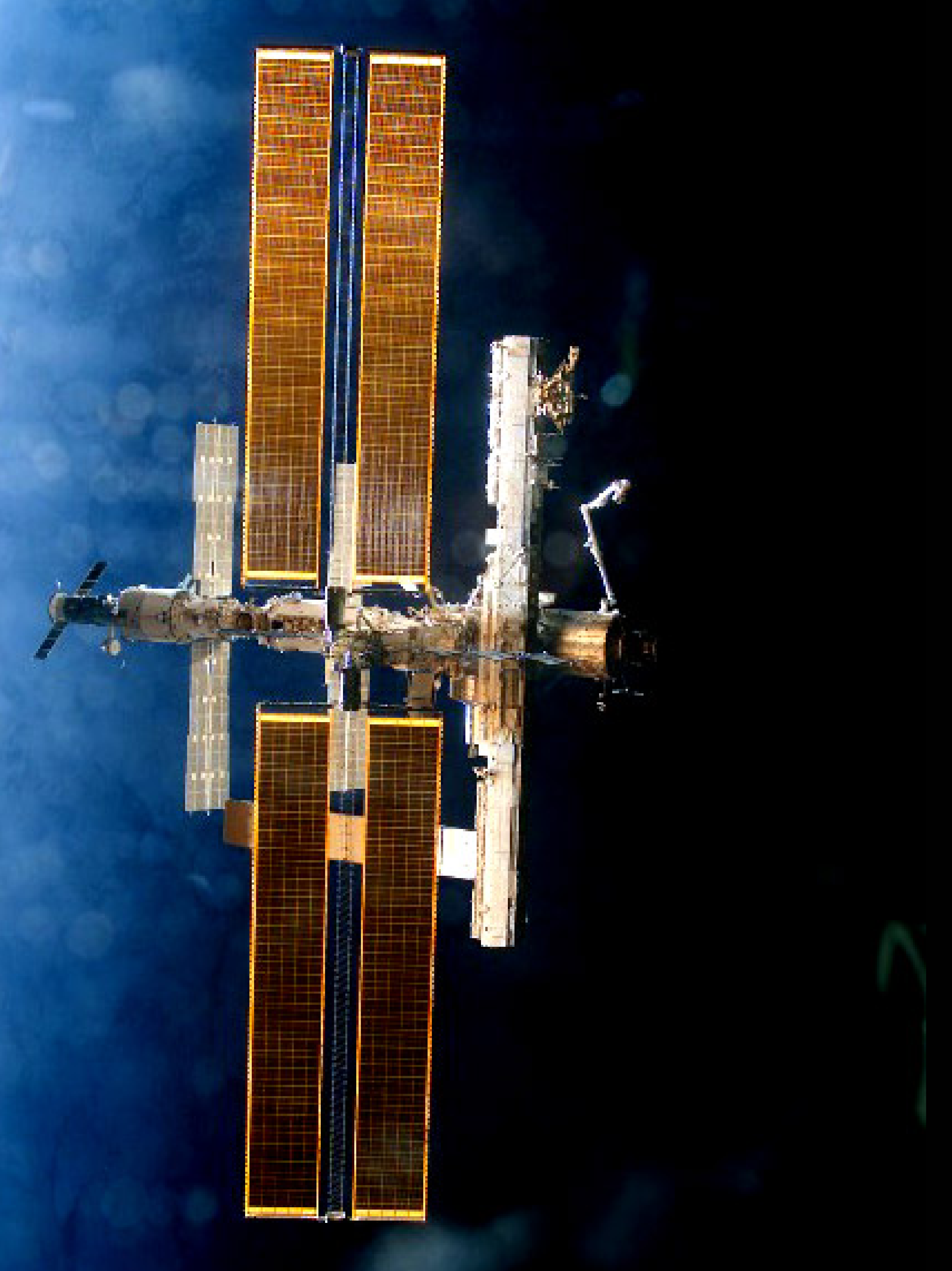
Getting outta there:

(An exercise for the new folks)

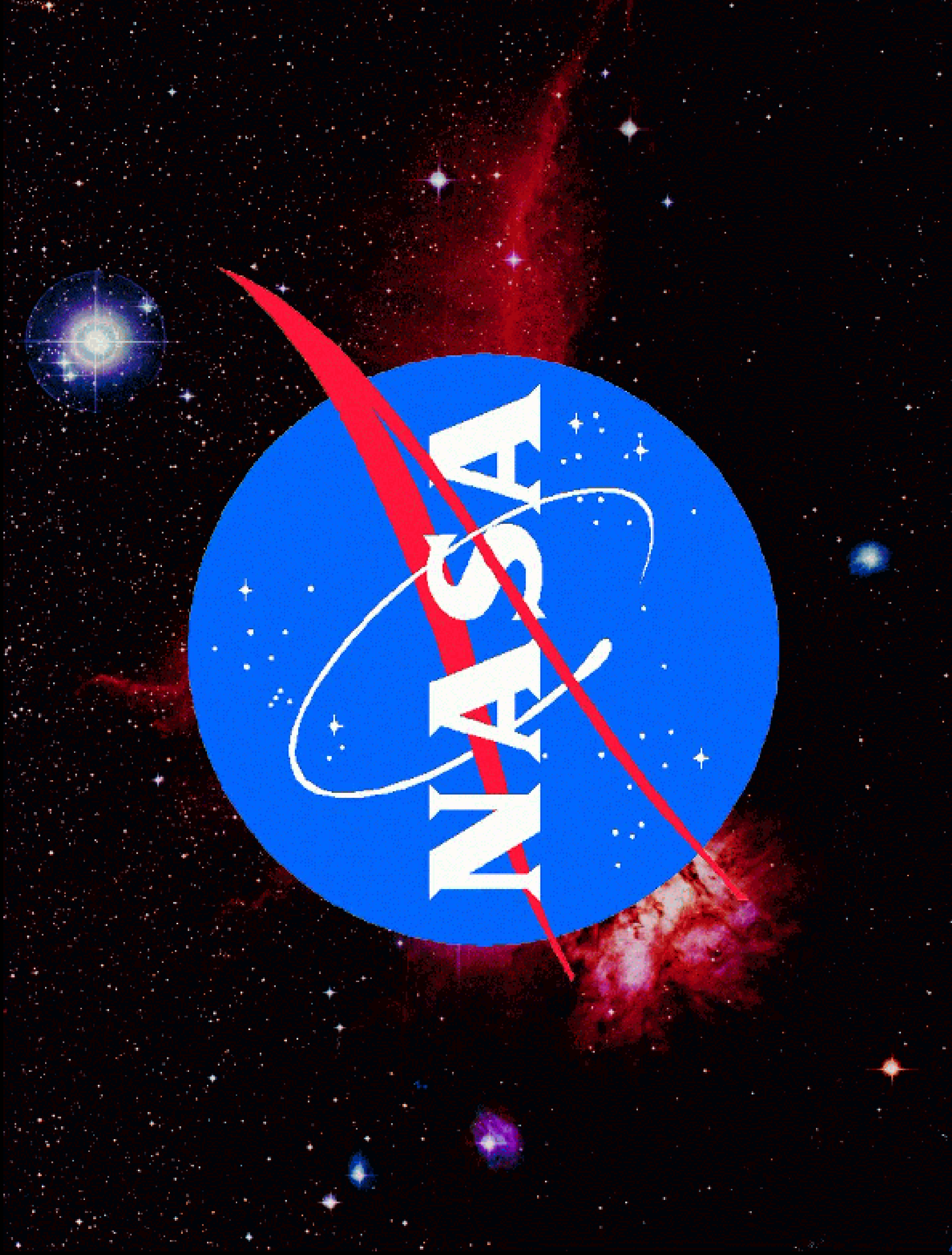


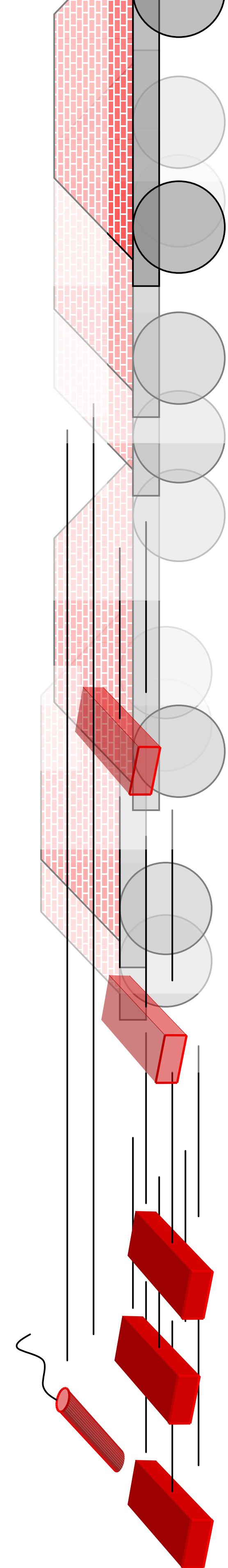


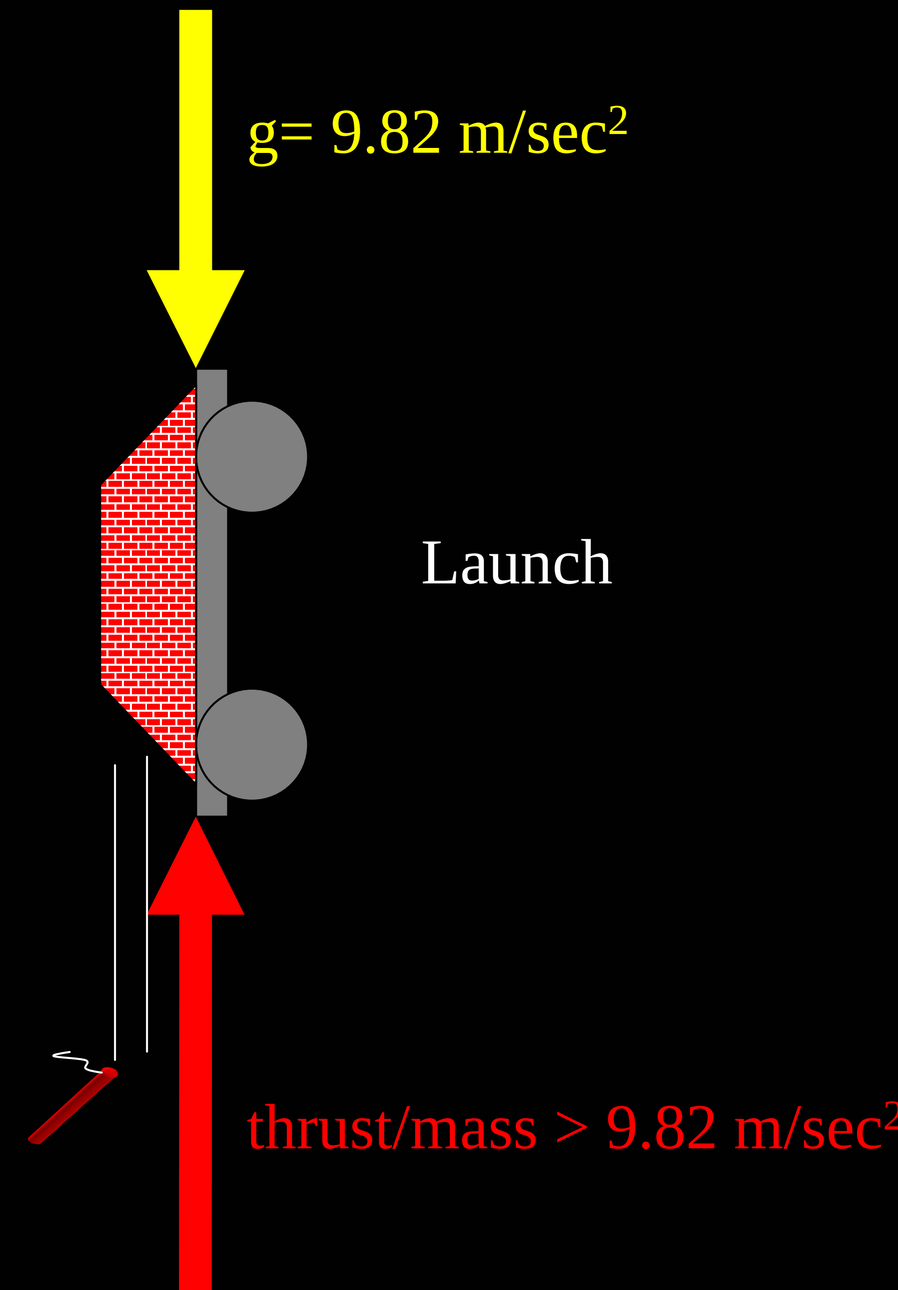


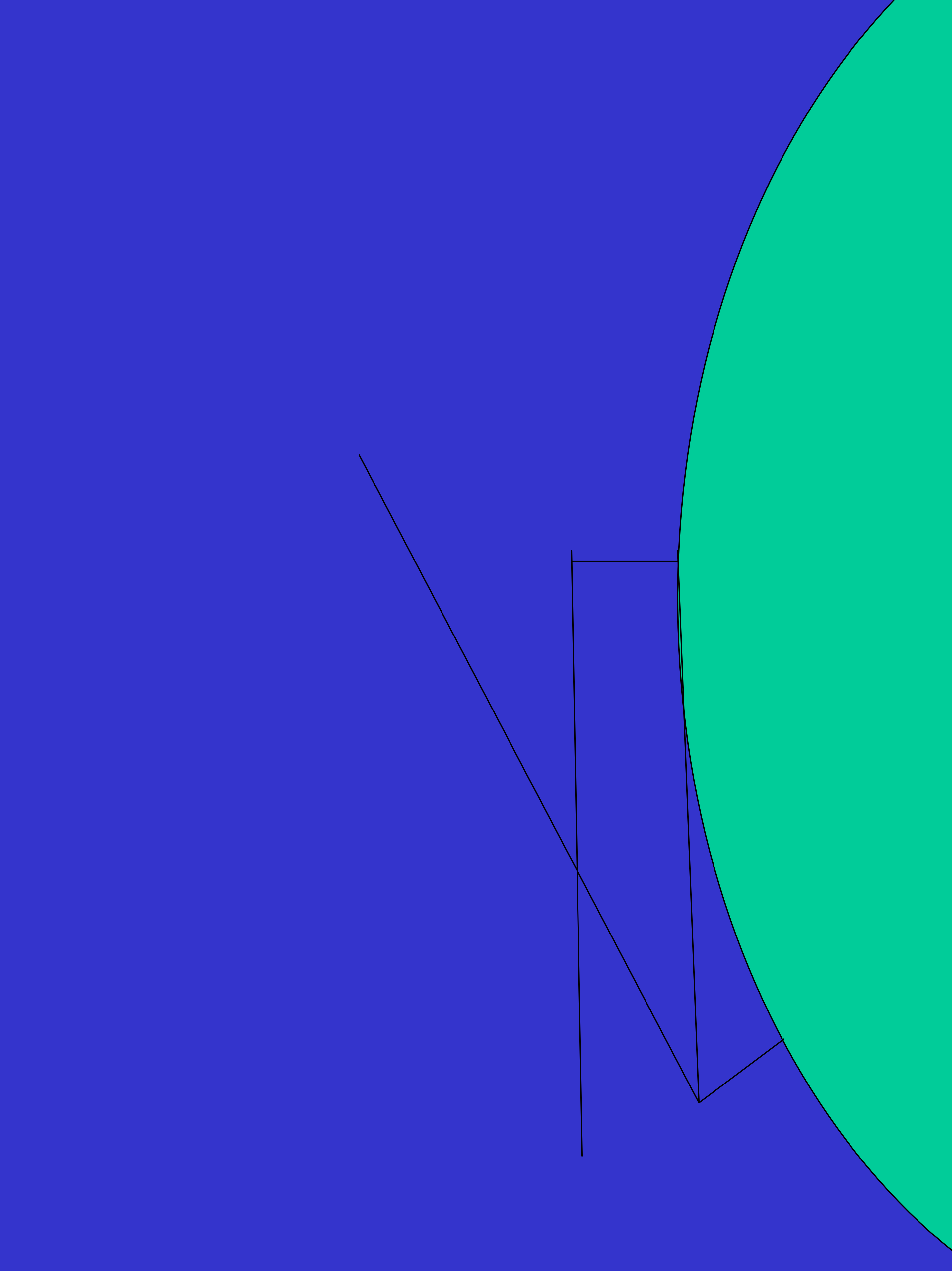


Planning down here:
(The BASEPLATE)

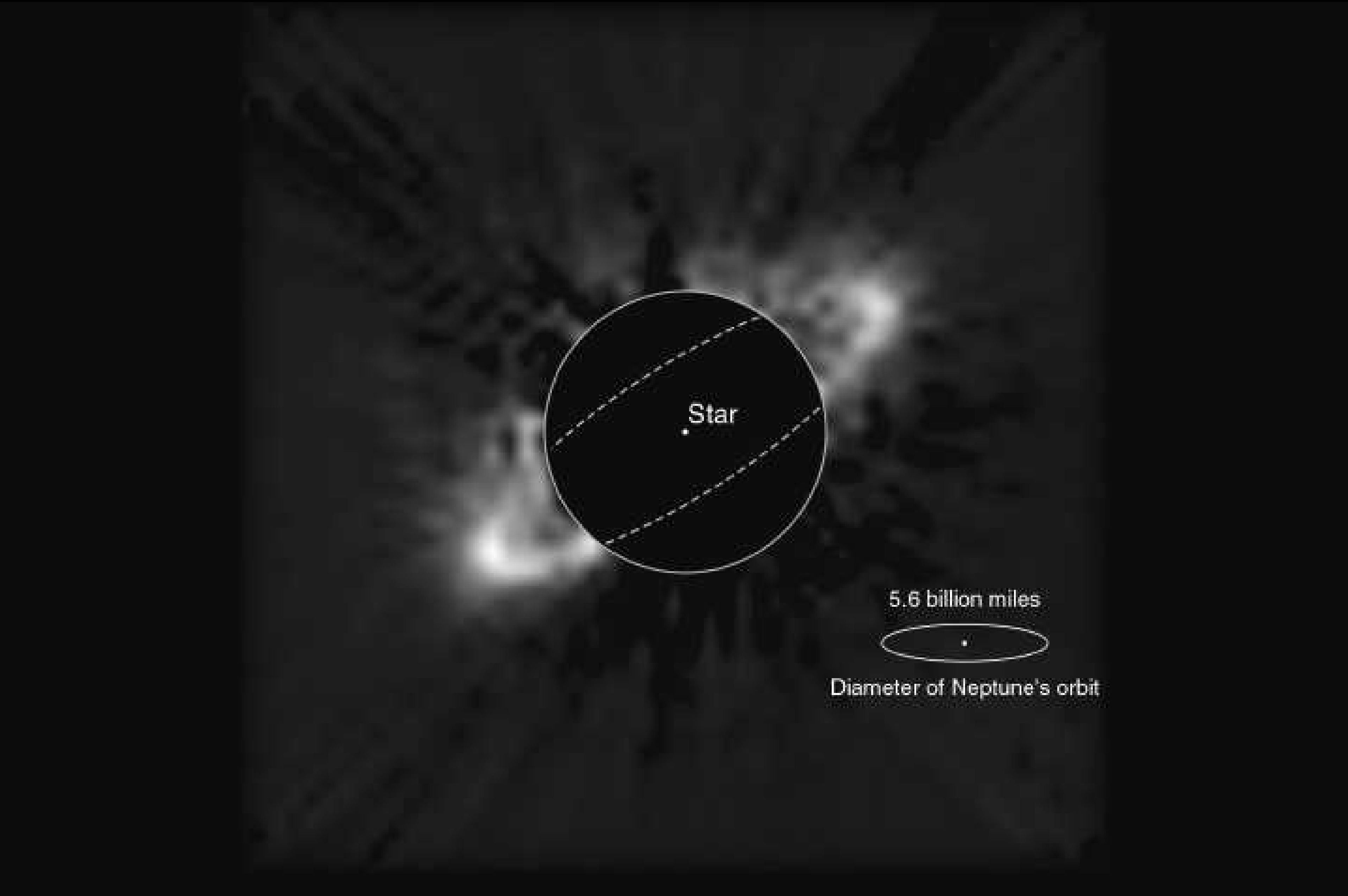

NASA




g= 9.82 m/sec²
Launch
thrust/mass > 9.82 m/sec²



**http://
usa1.unitedspacealliance.com/usahou/
projects/trn_academy/ta/
course.htm**


Star
5.6 billion miles
Diameter of Neptune's orbit

Density at 300 Km (Kg/m^3)